



Water and Wastewater Industry Energy Efficiency: A Research Roadmap

Project #2923
Subject Area:
Efficient and Customer-Responsive Organization

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Water and Wastewater Industry Energy Efficiency: A Research Roadmap

The mission of the Awwa Research Foundation (AwwaRF) is to advance the science of water to improve the quality of life. Funded primarily through annual subscription payments from over 1,000 utilities, consulting firms, and manufacturers in North America and abroad, AwwaRF sponsors research on all aspects of drinking water, including supply and resources, treatment, monitoring and analysis, distribution, management, and health effects.

From its headquarters in Denver, Colorado, the AwwaRF staff directs and supports the efforts of over 700 volunteers, who are the heart of the research program. These volunteers, serving on various boards and committees, use their expertise to select and monitor research studies to benefit the entire drinking water community.

Research findings are disseminated through a number of technology transfer activities, including research reports, conferences, videotape summaries, and periodicals.

Water and Wastewater Industry Energy Efficiency: A Research Roadmap

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FOREWORD

The Awwa Research Foundation is a nonprofit corporation that is dedicated to the implementation of a research effort to help utilities respond to regulatory requirements and traditional high-priority concerns of the industry. The research agenda is developed through a process of consultation with subscribers and drinking water working professionals. Under the umbrella of a Strategic Research Plan, the Research Advisory Council prioritizes the suggested projects based upon current and future needs, applicability, and past work; the recommendations are forwarded to the Board of Trustees for final selection. The foundation also sponsors research projects through the unsolicited proposal process; the Collaborative Research, Research Applications, and Tailored Collaboration programs; and various joint research efforts with organizations such as the U.S. Environmental Protection Agency, the U.S. Bureau of Reclamation, and the Association of California Water Agencies.

This publication is a result of one of these sponsored studies, and it is hoped that its findings will be applied in communities throughout the world. The following report serves not only as a means of communicating the results of the water industry's centralized research program, but also as a tool to enlist the further support of the nonmember utilities and individuals.

Projects are managed closely from their inception to the final report by the foundation's staff and large cadre of volunteers who willingly contribute their time and expertise. The foundation serves a planning and management function and awards contracts to other institutions such as water utilities, universities, and engineering firms. The funding for this research effort comes primarily from the Subscription Program, through which water utilities subscribe to the research program and make an annual payment proportionate to the volume of water they deliver and consultants and manufacturers subscribe based on their annual billings. The program offers a cost-effective and fair method for funding research in the public interest.

A broad spectrum of water supply issues is addressed by the foundation's research agenda: resources, treatment and operations, distribution and storage, water quality and analysis, toxicology, economics, and management. The ultimate purpose of the coordinated effort is to assist water suppliers to provide the highest possible quality of water economically and reliably. The true benefits are realized when the results are implemented at the utility level. The foundation's trustees are pleased to offer this publication as a contribution toward that end.

Edmund G. Archuleta, P.E.
Chair, Board of Trustees
Awwa Research Foundation

James F. Manwaring, P.E.
Executive Director
Awwa Research Foundation

The Public Interest Energy Research Program (PIER) supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Commission), annually awards up to \$62 million to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following six RD&D program areas:

- Buildings End-Use Energy Efficiency
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy
- Environmentally-Preferred Advanced Generation
- Energy-Related Environmental Research
- Strategic Energy Research

What follows is the final report for the Water and Wastewater Industry Energy Efficiency Research Roadmap. The report is entitled *Water and Wastewater Industry Energy Efficiency: A Research Roadmap*. This project contributes to the Industrial/Agricultural/Water End-Use Energy Efficiency program.

For more information on the PIER Program, please visit the Commission's Web site at <http://www.energy.ca.gov/research/index.html> or contact the Commission's Publications Unit at 916-654-5200.

PREFACE

The California Energy Commission (Commission) and the Awwa Research Foundation (AwwaRF) entered into a joint effort to identify and fund energy efficiency research projects that address pressing needs in the water and wastewater arena. The roadmap was created through the collective efforts of a group of public and private sector experts in water and wastewater energy use and research needs. The goal of the *Water and Wastewater Industry Energy Efficiency: A Research Roadmap* is to identify and prioritize research areas and projects that will advance emerging technologies and best practices to improve energy efficiency, reliability and costs for water and wastewater treatment facilities. The Steering Committee for the Roadmap effort consisted of:

- Paul Roggensack, California Energy Commission
- Linda Reekie, Awwa Research Foundation
- Shahid Chaudhry, California Energy Commission
- Brad Coffey, Metropolitan Water District of Southern California
- Shivaji Deshmukh, Orange County Water District
- Bill Idzerda, San Francisco Public Utilities Commission
- Lory Larson, Southern California Edison
- George Tchobanoglous, University of California Davis

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Joe Young — EBMUD

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Paul Roggensack — California Energy Commission
Linda Reekie — Awwa Research Foundation
Jennifer Warner — Awwa Research Foundation

Special thanks goes to the project team including Lorena Ospina and Michelle Matthes who coordinated the workshop, helped prepare the workshop materials and provided significant administrative and technical input into the project. Finally, the AwwaRF Project Manager, Ms. Linda Reekie, lent her expertise and project management insight in guiding the project. Thank you Linda.

EXECUTIVE SUMMARY

The California Energy Commission (Commission) and the Awwa Research Foundation (AwwaRF) jointly sponsored the development of this report *Water and Wastewater Industry Energy Efficiency: A Research Roadmap*.

The Roadmap is designed to satisfy two requirements:

1. Provide direction for the RD&D activities of the California Energy Commission's Public Interest Energy Research (PIER) program to meet the energy needs and priorities of the water and wastewater utilities based on the industry input.
2. Provide specific project descriptions which AwwaRF can incorporate in request-for-proposals.

The Roadmap was developed through the collective contribution of public and private sector experts in energy use in water and wastewater utilities. The participants represented water and wastewater utilities, energy utilities, consultants, academia, government and other research organizations.

The workshop participants identified eight primary research areas that represent potentially high yield in terms of energy savings and economic value. These areas are:

1. Advanced treatment processes
2. Desalination
3. Energy generation and recovery
4. Societal and institutional issues
5. Energy optimization
6. Sustainability
7. Decentralization
8. Total energy management.

A total of 44 project descriptions were identified and described within these eight areas. A detailed matrix ([Appendix B](#)) outlines the project titles, budget estimates, schedule and general rankings by potential savings, likelihood of success, and timeliness.

The projects represent potential funding opportunities for the Commission/AwwaRF research partnership. These projects and areas of research represent a pool of potentially fundable work that can generate energy and cost savings for California and for the drinking water and wastewater community.

The eight primary research areas address five key issues to achieving energy efficiency in the water and wastewater industries. An issue under the PIER program is defined as a broad statement of a problem for which resolution is essential to reduce the cost or improve the reliability and availability of energy. These key issues are:

1. Rising electricity costs to meet stringent water quality requirements
2. Rising electricity costs to enhance water supplies
3. Improving reliability to mitigate problems of grid and restructuring
4. Lack of a system-level energy-water link perspective for increasing energy efficiency
5. Non-technical barriers to optimize energy use and to foster energy savings

Mitigation of these issues is essential for meeting the PIER program objectives and of Energy Action plan adopted by the California Energy Commission. In addition, because of the rising energy costs and uncertainty regarding the supply and distribution of electricity, resolution of these issues are also relevant for other regions of the country.

The 44 proposed projects identify targets and approaches within the primary research areas to meet these issues. [Appendix E](#) contains an explanation on the development of the targets and approaches from the proposed projects to meet these key issues.

CHAPTER 1 INTRODUCTION

The infrastructure that collects, delivers and treats our water and wastewater includes reservoirs, pipelines, treatment plants, pumping plants, hydroelectric facilities, and waste disposal facilities. This infrastructure is managed through public systems and private business. The geographic distribution of communities has given rise to thousands of water and wastewater utilities in the state of California.

These water and wastewater utilities in California (as in other states) are currently grappling with significant demographic, environmental, and technological trends that will reshape the provision of these essential infrastructure services. The State of California's Department of Finance has estimated that the state population will increase from 34,480,300 in 2000 to 45,821,900 in 2020 (California Dept. of Finance 2001). These 11 million new residents will require water and wastewater service. This growth will have direct and indirect impacts on the provision of these services. For example, continued watershed development to accommodate this population growth has the potential to increase pollutant loading in municipal water treatment facilities, driving the installation of advanced water treatment technologies.

In addition, compliance with the regulatory requirements enacted under the Clean Water Act and the Safe Drinking Water Act will require many water and wastewater systems to implement new technologies like ultraviolet light oxidation/disinfection, integrated membranes, ozonation, etc.

Also, many of the current water and wastewater plants in California are thirty or more years old. The repair, upgrade, and replacement of this infrastructure will leverage new water treatment technologies and equipment.

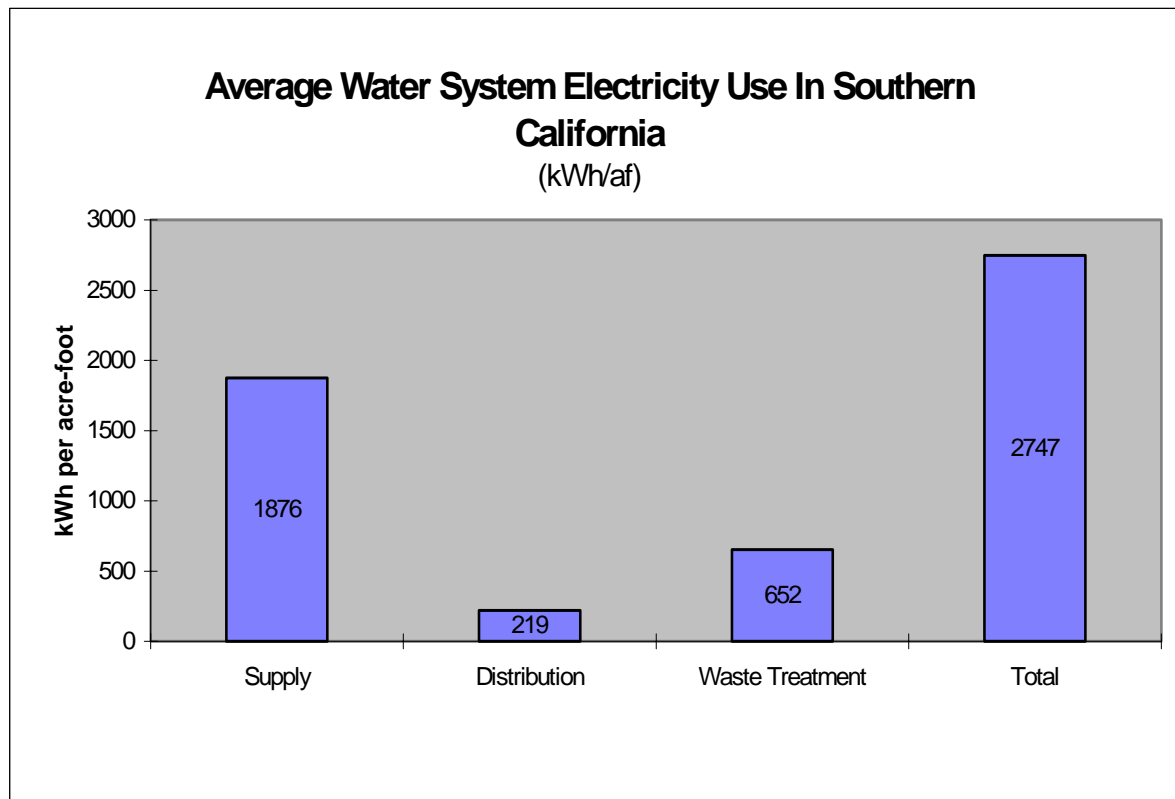
The energy requirements of these new energy intensive technologies must be planned for and accommodated. In light of these trends, significant opportunities exist to reduce energy use in water and wastewater systems.

The Energy Profile of Water and Wastewater Service Provision

In order to place this Roadmap in context with energy usage in the water and wastewater service industry, a brief review of the components of energy usage is provided. Detailed discussion of these components is available elsewhere in the literature.

A significant amount of energy is needed to deliver water and wastewater service to the home. For example, energy requirements to deliver water to residential customers in Southern California have been estimated to equal as much as 33

percent of the total average household electricity use (MWD 1999). Nationally, water and wastewater systems have been estimated to account for 4% of total electricity demand (EPRI 2002). Water systems in California are estimated to use about 6.9% of the state's electricity. The relative split between water and wastewater energy use in Southern California is depicted in [Figure 1.1](#).



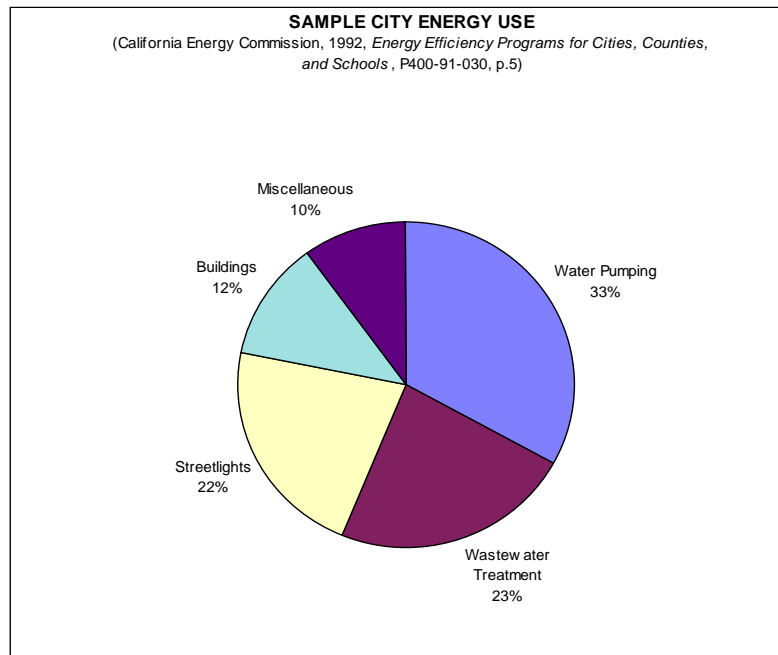
Source: QEI, Inc., 1992

Figure 1.1: Average Water System Electricity Use in Southern California

Pumping costs to deliver the water supply to the customer comprise the largest component of energy usage (approximately 68%) in the water/wastewater sector. Waste treatment comprises approximately 24% of energy use.

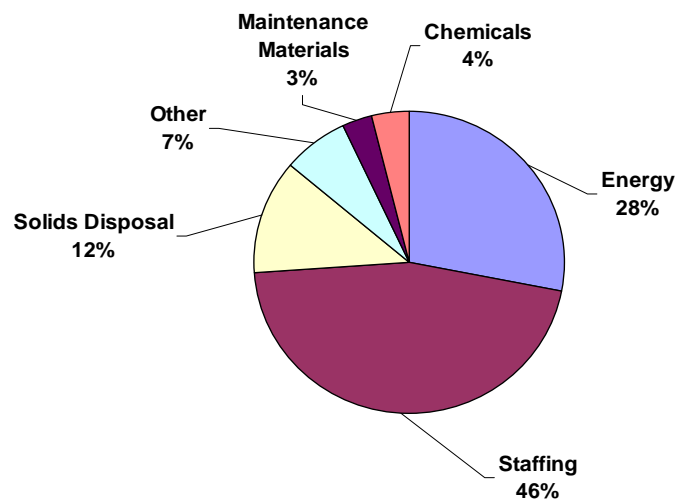
The actual use of electricity in water and wastewater management varies by utility and region (CEC 1992). An example of a typical city energy budget is shown in [Figure 1.2](#). In a typical city energy budget, the cost of providing water and sewer service is dominant. Water pumping and wastewater treatment energy consumption can comprise 56% of municipal energy use. Accordingly, the potential for energy savings is significant.

Energy use comprises approximately 28% of the cost of providing wastewater service ([Figure 1.3](#)).



Source: CEC 1992

Figure 1.2: Sample City Energy Use



Source: Global Energy Partners LLC

Figure 1.3: Cost Breakdown for Wastewater Systems

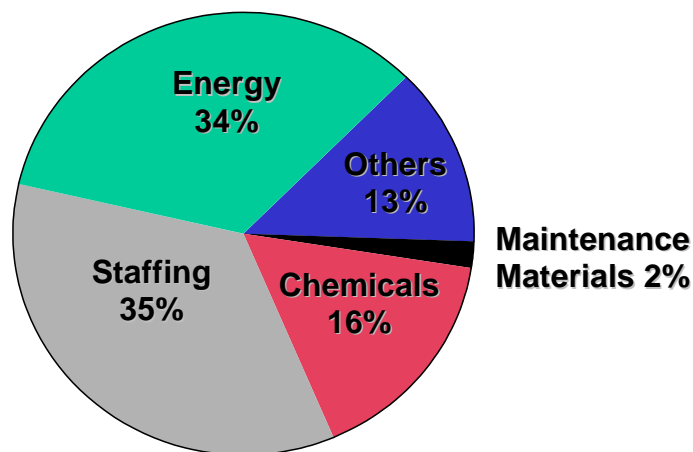
Distribution of energy consumption was studied at municipal wastewater facilities in a 2001 study by Quantum Consulting, Inc., for the Northwest Energy Efficiency Alliance ([Table 1.1](#)). While these figures represent energy usage in the northwest, they are likely typical figures. The activated sludge process dominated other wastewater treatment processes in terms of energy consumption.

Table 1.1: Distribution of Energy Consumption (GWh) at Municipal Wastewater Treatment Facilities by Size and Treatment Type

Process	Large	Medium	Small	Total
Activated Sludge	247	338	36	621
Lagoon	12	39	19	70
Oxidation Ditch	16	6	0	22
Trickling Filter	0	30	4	34
Unknown/Other	125	84	41	250
Grand Total	400	497	100	997

Source: Quantum Consulting 2001

[Figure 1.4](#) depicts the cost categories for the provision of municipal water supply service. Energy costs are nearly equal to staffing costs. Energy use in drinking water supply comprises 34% of the cost of providing the service.



Source: Global Energy Partners LLC

Figure 1.4: Cost Categories for Municipal Water Supply

Although there is considerable potential to improve the energy efficiency of water and wastewater utilities in California, California has the fourth lowest per capita rate of energy consumption as compared to other states (California Dept. of Energy 1999). Among the 19 most populous states — those with more than five million people — California ranks second lowest in per capita consumption, behind New York. Texas and California together accounted for more than one-fifth of the Nation's total energy consumption in 1999.

Water and wastewater service delivery is energy intensive. The increasing population in California (and elsewhere in the United States) will require the development of new water and wastewater infrastructure. The increasing age of infrastructure will require replacement. The development and selection of new technology will drive energy use in these sectors. Accordingly, efforts to optimize energy efficiency in existing water and wastewater systems and the facilitation of new energy efficient technologies have the potential to save significant energy resources. It is clear that efforts to minimize the use of energy in the production of drinking water and wastewater services can potentially yield substantial energy savings.

These savings can pay off in multiple ways including:

- Reducing pressure on rivers for hydroelectric generation
- Reducing emissions from generating plants using fossil fuels
- Reducing the cost of water and wastewater to the consumer and
- Reducing the consumption of energy resources.

Role of the California Energy Commission

The Commission has articulated a vision and strategy for achieving water and wastewater energy use efficiency through the Public Interest Energy Research Program (PIER Program). This vision directs research dollars to projects and areas of research that have the greatest promise to help improve the quality of life in California by bringing environmentally safe, affordable and reliable energy services and products to the marketplace.

The PIER Program was implemented in 1996. It is a public interest energy research, development and demonstration program. The objective of the PIER Program is to help improve energy efficiency as well as demonstrate new technologies, which would help various sectors deal with sustained energy and reliability issues.

The PIER program is organized into six programs, including:

- Residential and Commercial End-Use Energy
- Industrial/Agricultural/Water (IAW) End-Use Energy Efficiency

- Renewable Energy Technologies
- Environmentally-Preferred Advanced Generation (EPAG)
- Energy-Related Environmental Research
- Energy Systems Integration (EIS)

In addition, the PIER program conducts the Energy Innovation Small Grant Program, which funds early feasibility research in new technology for the six PIER program areas.

The development of this Roadmap continues the tradition of the Commission to remain vital and responsive to changes in energy use and technology.

Role of the Awwa Research Foundation

The Awwa Research Foundation is a member-supported, international, nonprofit organization that sponsors research to enable water utilities, public health agencies and other professionals provide safe and affordable drinking water to consumers. It is comprised of member utilities, consultants, vendors, and others that contribute towards a research fund (also supplemented by the federal government) that conducts peer-selected and reviewed research. Since the inception of its research subscription program in 1986, AwwaRF has funded hundreds of research efforts in virtually every aspect of water supply. AwwaRF has historically developed and funded energy related research in drinking water as one of the research areas of focus.

The Commission and AwwaRF have developed a partnership to identify and fund energy related research in water and wastewater. This Roadmap was initiated under this partnership and was designed to establish potential promising projects that could be solicited from the research community as part of a pilot water and wastewater energy research agenda.

CHAPTER 2 DEVELOPMENT OF THE ROADMAP

Roadmap Approach

The Commission and AwwaRF jointly sponsored the development of this *Water and Wastewater Industry Energy Efficiency: A Research Roadmap*.

The Roadmap is designed to satisfy two requirements:

1. Identify the energy needs for the water and wastewater industries based on industry input for the Commission to direct research, development and demonstration funding under the PIER program, and,
2. Provide specific project descriptions which AwwaRF can incorporate in request-for-proposals.

The Roadmap was developed through the collective contribution of public and private sector experts in energy use in water and wastewater utilities. These experts were identified by a steering committee and selected based upon their expertise, willingness to participate and availability. The steering committee consisted of:

- Paul Roggensack, California Energy Commission
- Linda Reekie, Awwa Research Foundation
- Shahid Chaudhry, California Energy Commission
- Brad Coffey, Metropolitan Water District of Southern California
- Shivaji Deshmukh, Orange County Water District
- Bill Idzerda, San Francisco Public Utilities Commission
- Lory Larson, Southern California Edison
- George Tchobanoglous, University of California Davis

The participants in the February 25-26, 2003 Water and Wastewater Energy Efficiency Research Needs Workshop in Sacramento California included:

- Thomas R. Alspaugh, P.E., City of San Diego Metropolitan Wastewater Engineering
- Dave Beyer, Water System Engineering, East Bay Municipal District
- Richard Butler, King County South Wastewater Treatment
- Keith Carns, P.E., DEE, Global Energy Partners



- Shahid Chaudhry, California Energy Commission
- Brad Coffey, P.E., Metropolitan Water District of Southern California
- Shivaji Deshmukh, P.E., Orange County Water District
- Simon Eching, California Department of Water Resources
- Mark Esquer, Orange County Sanitation District
- R. Neal Elliott, Ph.D., P.E., American Council for an Energy Efficient Economy (ACEEE)
- Stephen Fok, Pacific Gas and Electric Company
- Kevin Fisher, Las Vegas Valley Water District
- F. Bailey Green, Ph.D., PE, Lawrence Berkely National Lab
- Tom Hinkebein, Sandia National Laboratories
- David Huey, Contra Costa Water District
- Bill Idzerda, San Francisco PUC
- Reza Iranpour, Ph.D, PE, Bureau of Sanitation City of Los Angeles
- Janet Joseph, New York State Energy Development Authority (NYSERDA)
- Lory E. Larson, P.E., Southern California Edison
- Sherman May, Sherman May Consulting, Inc.
- Dale Newkirk, P.E., Damon S. Williams Associates
- Jim Parks, Sacramento Municipal Utility District
- Kevin Price, U. S. Bureau of Reclamation
- Roy Ramani, Water Environment Research Foundation
- David J. Reardon, P.E., HDR Engineering, Inc
- Linda Reekie, Awwa Research Foundation
- Paul Roggensack, California Energy Commission
- Fred Soroushian, P. E., CH2MHILL
- Michael K. Stenstrom, Ph.D., UCLA - Civil & Environmental Eng.Dept.
- Jennifer Warner, Awwa Research Foundation
- Ed Wheless, Los Angeles County Sanitation District
- Robert Wilkinson, University of California-Santa Barbara

The participants represent the general sectors depicted in [Table 2.1](#). (The numbers sum to greater than the total participants as some participants brought expertise in both water and wastewater.)

The workshop was facilitated by Mr. Ed Means of McGuire Environmental Consultants, Inc., and the workshop agenda is included as [Appendix C](#).

Table 2.1: Composition of Workshop Participants

	Utility	Consultant	Academia	Government	Other
Water	5	6	3	6	5
Wastewater	5	5	3	6	4

The workshop participants were provided background information on water and wastewater utility energy issues and asked, in advance, to submit potential project ideas. The ideas were also circulated among the participants in advance of the workshop. The workshop used breakout groups to debate and refine project ideas, and establish estimated project costs and schedule. The breakout groups were asked to evaluate the projects and assign a score of one to three in each of three categories:

1. *Savings Potential* – The projects having the greatest potential for both energy and economic savings were assigned a score of three.
2. *Likelihood for Success* – The projects having the greatest likelihood of being implemented and introduced to the marketplace were assigned a score of three.
3. *Timeliness* – The projects expected to produce the most recognizable benefits within a reasonable period of time were assigned a score of three.

Additionally, the projects were qualitatively ranked by the participants through a “dot-voting” process where, at the conclusion of the workshop, each participant was provided 5 votes to apply to one or several of the projects to signify their view regarding priority for funding. These votes (dots) were applied to the project titles displayed on posters and conducted in a group setting. The process was not intended to be the ultimate forced ranking of projects but rather to generally signify the sentiment of the group.

The project title, budget, schedule and rankings were summarized in a project matrix ([Appendix B](#)). Abstracts of each research idea were generated and are included in [Appendix A](#).

The Roadmap

The workshop participants identified eight primary research areas that represent potentially high yield in terms of energy savings and economic value. These areas are:

1. Advanced treatment processes
2. Desalination
3. Energy generation and recovery
4. Societal and institutional issues
5. Energy optimization
6. Sustainability
7. Decentralization
8. Total energy management

Potential project ideas developed by the participants are summarized under each of the eight primary research areas and further descriptions are included in [Appendix A](#). The relationship between the eight research areas and the PIER Program is discussed in [Appendix E](#).

1. Advanced Treatment Processes

Several new energy intensive technologies are being deployed in the water and wastewater utility sector. These technologies are being deployed to ensure compliance and control costs (including energy costs). In addition, the water needs of a growing population are rapidly outstripping the ability to tap traditional sources of water supply in the United States. Communities are increasingly turning to lower quality sources of supply and implementing sophisticated advanced treatment to meet stringent drinking water regulations. These new technologies include the expanded use of microfiltration, ultrafiltration, nanofiltration, and reverse osmosis membranes, ozone and ultraviolet light disinfection/oxidation technologies (and others).

At the workshop, participants identified needs for the primary research areas. Some of these needs could potentially or partially be met by the project ideas identified at the workshop. An asterisk designates cases where the group did not identify potential solutions. [Table 2.2](#) summarizes the needs for the primary research area of *Advanced Treatment Processes* and project ideas that could contribute to the solutions.

Table 2.2: Advanced Treatment Processes Research Needs and Potential Solutions

ADVANCED TREATMENT PROCESSES	
Needs	Potential Solutions
Alternative disinfection systems for microbially and chemically challenged water and wastewater including ozone, UV, chlorine dioxide and gaseous/liquid chlorine	#3: UV Optimization Guidance Manual #7: Advanced Treatment of Delta Water to Meet Future Regulations #20: UV Disinfection: Develop Next-Generation Energy Efficient UV Disinfection Systems for Water and Wastewater Treatment #30: Peracetic Acid Pilot Study for Effluent Disinfection #42: Use of Chlorine Dioxide and Ozone for Control of Disinfection By-Products in a Full-Scale Demonstration
Energy efficient advanced oxidation for organic compounds in water and wastewater	#6: Catalytic Advanced Oxidation Systems (continued)

Table 2.2 (Continued)

Needs	Potential Solutions
Advanced, energy efficient treatment technologies for biosolids	#12 Use of Membranes for Treatment of Biosolids Processing Recycles
Biological treatment technologies (e.g. anaerobic/aerobic membrane bioreactors, biological nutrient removal) for wastewater	#18:Development of Anaerobic Treatment Technologies for Municipal Wastewater Treatment
Separation technologies including membrane filtration for primary treatment and secondary treatment	#18:Development of Anaerobic Treatment Technologies for Municipal Wastewater Treatment
Advanced primary treatment	#28:Primary Effluent Microfiltration – Secondary Treatment Alternative
Solids handling (dewatering optimization)	#13: Development of High Solids, Vertical, Plug Flow Anaerobic Digestion #23: Waste Activated Sludge Conditioning Prior to Anaerobic Digestion to Enhance Treatability and Dewatering #31: Recuperative Thickening of Anaerobic Digestion for Enhanced Gas Production
Advanced digestion technologies	#18:Development of Anaerobic Treatment Technologies for Municipal Wastewater Treatment
Synergistic effects of treatment processes in reducing energy consumption	#32: Energy-Efficient, Carbon-Efficient Alternative Advanced Wastewater Treatment
Energy use impacts due to regulatory requirements (discharge and water delivery)	#7: Advanced Treatment of Delta Water to Meet Future Regulations
Energy implications of new technologies to meet stringent arsenic standards	*

* The research need was identified but no specific example projects were generated.

The following are examples of research project descriptions developed at the workshop that will help provide solutions to the research needs identified in the area of *Advanced Treatment Processes*.

- **UV Optimization Guidance Manual-** As a new technology, most water and wastewater suppliers have only limited experience with the advantages, disadvantages and operating peculiarities of UV disinfection. This project would develop a UV optimization manual that could be used

by planners, engineers, treatment plant operators, and energy managers to provide objective guidance for the successful implementation of UV technology in an energy efficient manner.

- **Catalytic Advanced Oxidation Systems-** Advanced Oxidation Processes (AOPs) can be used to remove contaminants such as MTBE, NDMA and 1,4 dioxane, which are released in the environment and pass through wastewater treatment systems. The objective of this project would be to develop a more energy efficient AOP reactor to remove organic contaminants that pass through the reverse osmosis barrier, resulting in energy savings over conventional solution phase AOPs.
- **Advanced Treatment of Delta Water to Meet Future Regulations-** The objective of this project would be to determine the best means of optimizing advanced drinking water treatment technologies for energy utilization on the demonstration scale. This project would examine UV, membranes, ozone and multiple disinfectants.
- **UV Disinfection: Develop Next-Generation Energy Efficient and Effective UV Disinfection Systems for Water and Wastewater Treatment-** UV disinfection provides cost-effective inactivation of waterborne pathogens including *Cryptosporidium* and *Giardia*, all with out the formation of disinfection by-products but at high energy costs. The objective of this project would be the development or application of new equipment technologies, so as to explore other industry uses of UV applications for water and wastewater.
- **Peracetic Acid Pilot Study for Effluent Disinfection (P2)-** Peracetic acid has been demonstrated as a strong disinfectant but is primarily used in other industries. The objective of this project would be to demonstrate the use of peracetic acid, to verify non-toxicity on plant effluent, and to determine whether any by-products of concern are generated by its use.
- **Use of Chlorine Dioxide and Ozone for Control of Disinfection By-Products in a Full Scale Demonstration-** Ozone has replaced chlorine as a disinfectant at many treatment plants as a means of eliminating trihalomethanes. This project would determine the energy savings potential from incorporating ClO_2 as a pre-oxidant necessary to achieve required reduction of disinfection by-products.
- **Use of Membranes for Treatment of Biosolids Processing Recycles-** The recycles generated from biosolids treatment processes contain high concentrations of ammonia, phosphorus, alkalinity, total dissolved salts, and hardness. Physical/chemical treatment processes such as the use of membranes, distillation, and ammonia stripping/neutralization options

could be utilized for treatment of these side streams and would result in treatment cost-savings while recovering these valuable nutrients.

- ***Development of Anaerobic Treatment Technologies for Municipal Wastewater Treatment-*** Wastewater treatment is presently achieved by using aerobic processes, such as air-activated sludge. This project would develop and operate an anaerobic treatment system, coupled with membrane filtration, for wastewater treatment to investigate energy savings and power generation potential.
- ***Primary Effluent Microfiltration-Secondary Treatment Alternative-*** Activated sludge secondary treatment is very expensive and energy intensive to operate. The objective of this study is to demonstrate the use of membrane-filters in lieu of or in addition to, secondary treatment.

2. Desalination

Desalination of brackish water and ocean water is growing in popularity. There are numerous ocean water reverse osmosis facilities in planning, design, construction, and operation in the United States. Most of the activity is occurring in California, Texas, and Florida. As the cost of desalination drops (as membranes become commodities and their efficiencies improve) it is likely that desalinated supplies will become increasingly common. The energy demands of desalting are significant. Optimization of current membrane desalination processes and development of less energy intensive membrane processes can save significant energy resources.

As population levels increase, increasing pressure on existing water supplies will occur. This will drive the development of traditionally “marginal” supplies of water including water recycling, use of brackish groundwater, and desalination (agricultural drainage water, recycled water, brackish groundwater and ocean water). The extent to which this happens will be driven by the economics of water treatment technology and energy use (two major cost components of these water resource strategies).

Improvements in desalination technologies that reduce energy consumption are sought.

[Table 2.3](#) summarizes the needs for the primary research area of *Desalination* and project ideas that could contribute to addressing the needs.

Table 2.3: Desalination Research Needs and Potential Solutions

DESALINATION	
Needs	Potential Solutions
Characterization and evaluation of new or emerging technologies	#1: Review of International Desalination Research #37: Development of a Guidance Manual to Design/Operate Desalination Facilities for Maximum Energy Efficiency
Assessment of the water resource potential of brackish groundwater/wastewater	#33: Zero Liquid Discharge for In-Land Desalination
Improvements in membrane performance including the development of lower pressure membranes (e.g. reduce fouling, increase flux, improve rejection, increase integrity, increased longevity, etc.)	#29: Comparison of Electrodialysis Reversal (EDR) Costs and Performance to Low and High Pressure Reverse Osmosis (RO) Systems for Desalination
Pre-treatment systems	*
Post-treatment systems	#33: Zero Liquid Discharge for In-Land Desalination
Concentrate treatment and disposal strategies	#33: Zero Liquid Discharge for In-Land Desalination
Improvements in thermal processes	
Improvements in electrodialysis technology	#29: Comparison of Electrodialysis Reversal (EDR) Costs and Performance to Low and High Pressure Reverse Osmosis (RO) Systems for Desalination
Strategies to speed the development and adoption of new technologies	#1: Review of International Desalination Research
Strategies to speed the commoditization of membranes	*

The following are examples of research project descriptions developed at the workshop that will help provide solutions to the research needs identified in the area of *Desalination*.

- **Review of International Desalination Research-** The objective of this project would be to develop a reference document containing current research and development efforts in the international desalination community.

- ***Comparison of Electrodialysis Reversal (EDR) Costs and Performance to Low and High Pressure Reverse Osmosis (RO) Systems for Desalination-*** Reverse osmosis systems are energy intensive. New EDR systems tend to have high operation and maintenance costs. The objective of this project would be to confirm that EDR's operation and maintenance costs are not prohibitively high, and that their lower initial costs make them an alternative to RO.
- ***Zero Liquid Discharge for In-land Desalination-*** New cost-effective technologies need to be developed to dispose of desalination concentrate. The objective of this project would be to develop energy efficient, low cost methods of zero discharge for brackish water sources and toxic irrigation return flows.
- ***Development of a Guidance Manual to Design/Operate Desalination Facilities for Maximum Energy Efficiency-***Desalination is increasingly becoming a major source of new water supply. This technology is inherently energy intensive. The objective of this project would be to prepare a design/operating manual for the water community to guide their future operating plans (based upon current operating experience and conceptual design).

3. Energy Generation and Recovery

The recovery of wasted energy in water and wastewater processes has significant potential to save energy and money. These savings can derive from multiple areas including:

- Recovering lost energy resources from digester gas, excess head, waste heat, etc.
- Optimizing the use of standby generation (or otherwise maximizing the value of existing infrastructure)
- Blending energy resources (e.g., mixed fuels such as boosting digester gas with fossil fuel and supplementing digester feed with non-wastewater solids).

Improvements in energy generation and recovery can potentially reduce the cost of water and wastewater treatment. In addition, reduced use of fossil fuels, improved air quality and lowered demand for new generation facilities can result.

Table 2.4 summarizes the needs for the primary research area of *Energy Generation and Recovery* and project ideas that could contribute to addressing the needs.

Table 2.4: Energy Generation and Recovery Research Needs and Potential Solutions

ENERGY GENERATION AND RECOVERY	
Needs	Potential Solutions
Investigate and demonstrate the ability to recover previously lost energy resources	#5: Conversion of Digester Gas to Liquefied Natural Gas and Liquefied Carbon Dioxide #11: Development of In-Line, Continuous Thermal Hydrolysis for Improving Municipal Sludge Digestion #13: Development of High Solids, Vertical, Plug Flow Anaerobic Digestion #25: Recovery and Use of Digester Gas at Small Wastewater Treatment Plants
Maximize the value of existing infrastructure (use of standby generation)	*
Blending energy resources	*
Supplementing digester feed with non-wastewater solids	#16: Gas Enhancement During Anaerobic Process of Sewage Sludge by Co-digestion of Organic Solid Wastes
Dual fuel, backup power	#4: Dual Fueled Backup Generators (BUGS) for Reliability and Peak Shaving
Biogas cleanup	#14: Cost Effective Digester Gas Cleanup for Advanced Power Generation
Balancing on-site generation with grid support	#39: Digester Gas Storage for Improved Peak Power Management
In-line hydroelectric	*
Energy recovery and membranes	*#40: Membrane Separation of Methane and Carbon Dioxide and Sulfides from Digester Gas
Cogeneration	*
Power system integration	*
Interconnections	* (continued)

Table 2.4 (Continued)

Needs	Potential Solutions
Improve the efficiency and cost effectiveness of energy production	#23: Waste Activated Sludge Conditioning Prior to Anaerobic Digestion to Enhance Treatment and Dewatering #25: Recovery and Use of Digester Gas at Small Wastewater Treatment Plants #31: Recuperative Thickening of Anaerobic Digestion for Enhanced Gas Production #40: Membrane Separation of Methane and Carbon Dioxide and Sulfides from Digester Gas
Reduce the impacts of energy production	*
Improve the reliability and security of energy sources	*
Improve energy conservation and recovery	*
Develop renewable energy sources (other than digester gas)	*

The following are examples of research project descriptions developed at the workshop that will help provide solutions to the research needs identified in the area of *Energy Generation and Recovery*:

- ***Conversion of Digester Gas to Liquefied Natural Gas (LNG) and Liquefied Carbon Dioxide (CO₂)*** – Often, anaerobic digester gas from wastewater treatment plants (WWTP) is not reused due to insufficient recovery, capacity, economics, or air pollution limits. Flaring of this excess gas wastes the fuel value of the gas and adds air pollutants and green house gases to the atmosphere. The objective of this project would be to install the first digester gas liquefaction system to prove the technology's technical and economic viability.
- ***Development of In-line, Continuous Thermal Hydrolysis for Improving Municipal Sludge Digestion*** - The thermal hydrolysis systems currently employed consist of batch processes requiring steam injection, multiple tanks, and high operating pressures. This project would investigate the performance and cost of a continuous, in-line thermal hydrolysis system.

- ***Cost-Effective Digester Gas Cleanup for Advanced Power Generations*** - Wastewater treatment plant digester gas contains sulfur, halogenated hydrocarbons, and siloxanes that are harmful to post combustion emission control equipment. An important element to this project would be to show that the gas cleanup system would be cost effective and that the combined power cleanup and power-generating unit would produce electricity at competitive prices.
- ***Recovery and Use of Digester Gas at Small Wastewater Treatment Plants*** - Digester gas is routinely used at large treatment plants for power generation. This project would determine the technical or institutional barriers that prevent small plants from fully recovering the energy from digester gas.
- ***Gas Enhancement During Anaerobic Process of Sewage Sludge by Co-Digestion of Organic Solid Waste-*** Recovery of methane produced during digestion may reduce the total energy demand of wastewater treatment plants and thus provide a means to lower the plant's operational costs. One alternative to enhance methane production is by simultaneously digesting wastewater sludge with organic-rich wastes (co-digestion). This study evaluates the feasibility of co-digesting sewage sludge with other organic waste in order to enhance biogas production.

4. Societal and Institutional Issues

There is an opportunity to optimize existing policies, practices and perceptions to lower energy consumption associated with conveyance, treatment, distribution, use, and reclamation of water and wastewater. Examples include establishment of tiered water rates to reflect power costs (including time of use power/water pricing), evaluation of energy and water resource trade-offs with protection of beneficial use (regulations), identification of energy benefits of recycling and conservation, and review of costs and benefits of water exchanges. Developing a clear understanding of the energy implications of alternative water resource strategies may uncover significant potential energy savings. Similarly, the opportunities to preserve the benefits of regulation while improving energy efficiency are of interest. Public acceptance of alternative water supplies that consume less energy may require public education and risk communication.

Table 2.5 summarizes the needs for the primary research area of *Societal and Institutional Issues* and project ideas that could contribute to addressing the needs.

Table 2.5: Societal and Institutional Issues Research Needs and Potential Solutions

SOCIETAL AND INSTITUTIONAL ISSUES	
Needs	Potential Solutions
Develop understanding of energy implications of alternative water resource strategies	#17: Estimation of Embedded Energy in Water #27: Energy Consumption for Potable Water Conveyance and Treatment in Southern California Region #34: The Cost and Value of Recycled Water
Identify institutional barriers to infrastructure finance	*
Provide zero interest financing for innovative ideas and advanced technologies	*
Pollution offset credits	*
Co-funding of energy savings programs through rates or incentives	*
Encouraging application of new or emerging technologies	#2: Water and Wastewater Treatment Plant Energy Efficiency Achievement Program #38: Identification and Evaluation of Innovative Water Treatment Processes
Conduct demonstration projects	#38: Identification and Evaluation of Innovative Water Treatment Processes
Develop Best Management Practices for industrial customers	#19: Development of Customized Pre-Treatment and Diversion Programs
Consider energy implications and cross-media impacts of regulations	#26a: Guidance Manual: Protecting Treated Water Quality While Reducing Energy Costs #26b: Guidance Manual: Protecting Distribution System Water Quality While Reducing Energy Costs

The following are examples of research project descriptions developed at the workshop that will help provide solutions to the research needs identified in the area of *Societal and Institutional Issues*:

- **Estimation of Embedded Energy in Water-** As the linkage between water consumption and energy consumption are explored, it would be valuable to estimate the typical energy use associated with the

consumption of a unit of treated water. This project would develop a national matrix that shows the relationship between water consumption and energy associated with water and wastewater treatment.

- ***Energy Consumption for Potable Water Conveyance and Treatment in Southern California Region-*** Alternative water supplies in Southern California require vastly different amounts of energy. This project would identify the current range of energy usage and energy costs for seawater desalination, and compare to the energy used to convey and treat imported and local supplies.
- ***Development of Customized Pre-Treatment and Diversion Program-*** Many wastewater treatment facilities are overtaxed by upstream users. Enhanced pretreatment and diversion by users would alleviate significant burdens on the wastewater facilities. The objective of this project would be to evaluate the customization of pretreatment programs for cost-effectiveness and energy efficiencies.
- ***Identification and Evaluation of Innovative Water Treatment Processes-*** Currently there is no process to actively identify innovative water treatment processes. Without this investment there will be no major advancement in treatment techniques. This project aims to identify innovative water research ideas, evaluate the potential advantages/disadvantages of these ideas based upon scientific principals, and assist in the demonstration of these processes.
- ***Cost and Value of Recycled Water-*** The economic and environmental costs of discharge may become prohibitively expensive. The objective of this project would be to conduct a university-based study of the cost of delivering reclaimed water with the cost of desalination and other potential water sources.

5. Energy Optimization

The energy intensive nature of water and wastewater infrastructure is driven by the physical need to pump and treat water. Energy costs represent approximately 28% and 34% of wastewater and water costs, respectively. Optimizing the existing systems for delivering and treating water and wastewater represent substantial energy savings.

Improving the pumps, mechanical equipment, and control systems represent opportunities to improve the energy efficiency of water. To this end, research into potential changes to existing processes and equipment that would reduce energy consumption/costs while maintaining quantity and quality is needed. Changes may include new instrumentation and controls, new operating

procedures, information systems, models, or adjusting operational parameters (pH, temperature, and dissolved oxygen).

Table 2.6 summarizes the needs for the primary research area of *Energy Optimization* and project ideas that could contribute to addressing the needs.

Table 2.6: Energy Optimization Research Needs and Potential Solutions

ENERGY OPTIMIZATION	
Needs	Potential Solutions
Pump and motor optimization	*
Automation strategies	#43: Process Optimization: Using Advanced Controls and On-Line Instrumentation to Increase Capacity, Improve Performance and Improve Energy Efficiency
Real-time monitoring and control systems	#43: Process Optimization: Using Advanced Controls and On-Line Instrumentation to Increase Capacity, Improve Performance and Improve Energy Efficiency
On-line instrumentation and improved sensors	#43: Process Optimization: Using Advanced Controls and On-Line Instrumentation to Increase Capacity, Improve Performance and Improve Energy Efficiency
Development of decision support tools	#9: Best Forecasting Tools for Predicting Water Demands for Energy Optimization of Pumping Plants #10: Energy Consumption of UV and Chlorine/Sodium Hypochlorite Disinfection #36: Thermodynamic Evaluation of Advanced Water and Wastewater Treatment Technologies
Power generation and pump storage optimization	#4: Dual Fueled Backup Generators (BUGS) for Reliability and Peak Shaving
Water conveyance optimization	#9: Best Forecasting Tools for Predicting Water Demands for Energy Optimization of Pumping Plants
	(continued)

Table 2.6 (Continued)

Needs	Potential Solutions
Primary wastewater treatment optimization	#22: Enhancing Biological Oxygen Demand and Suspended Solids Removal Prior to the Activated Sludge Process in Wastewater Treatment Plants
Biological process optimization to save energy	#24: Barriers to Using Fine Pore Aeration Systems at Small Treatment Plants #32: Energy-Efficient, Carbon- Efficient Advanced Wastewater Treatment for Natural Systems
Waste activated sludge optimization to reduce biosolids production	#23: Waste Activated Sludge Conditioning Prior to Anaerobic Digestion to Enhance Treatability and Dewatering
Biosolids digestion optimization	#11: Development of In-Line, Continuous Thermal Hydrolysis for Improving Municipal Biosolids Digestion #13: Development of High Solids, Vertical Plug Flow Anaerobic Digestion #15: Energy Optimization of Thermophilic Anaerobic Digestion for Class A Biosolids Production #31: Recuperative Thickening of Anaerobic Digestion for Enhanced Gas Production
Development of reservoir operational models to maximize energy efficiency	*
Development of resource balancing models and management tools	#2: Water and Wastewater Treatment Plant Energy Efficiency Achievement Program #8: Development of a Utility Energy Index to Assist in Benchmarking of Energy Management for Water and Wastewater Utilities

The following are examples of research project descriptions developed at the workshop that will help provide solutions to the research needs identified in the area of *Energy Optimization*.

- ***Energy Consumption of Chlorine/Sodium Hypochlorite Disinfection and Dechlorination-*** As the price and technology for low and medium

pressure Hg UV are becoming more competitive, the need to benchmark the energy consumption of common alternatives becomes necessary for the identification of disinfection energy savings. This project would identify environmental, safety, and health impacts, quantify the impacts, if feasible, and compile a guidance manual.

- ***Best Forecasting Tool for Predicting Water Demands for Energy Optimization of Pumping Plants-*** This project would provide the data necessary for water utilities to select the “best” water demand forecaster capable of making accurate water demand forecasts. It involves evaluating available methods and programs (tools) for making water demand predictions, identifies criteria for the ranking of each tool, and tests/evaluates the performance of each forecasting tool.
- ***Development of High Solids, Vertical, Plug Flow Anaerobic Digestion-*** Anaerobic digestion of biosolids generated from wastewater treatment results in generation of digester gas (typically used for co-generation) and reduction of the biosolids mass to reuse/disposal sites. An unmixed or partially mixed, vertical, plug flow digester operating at a solids content of 12% to 20% could substantially reduce digester volume as well as mixing power and heating energy requirements.
- ***Energy Optimization of Thermophilic Anaerobic Digestion for Class A Biosolids Production-***Optimization of the digester temperature has a greater impact of the energy demand and cost of operation of wastewater treatment plants because of the large volume of waste sludge that needs to be treated. This project would determine the lowest temperature for operation of thermophilic digesters in order to minimize energy use.
- ***Waste Activated Sludge Conditioning Prior to Anaerobic Digestion to Enhance Treatability and Dewatering-*** Waste activated sludge is a problem at WWTPs. It is difficult to dewater, does not degrade easily in the digestion process, and produces large volumes of residuals for disposal. Proper conditioning of this sludge prior to digestion could reduce the problems and enhance biogas production in digesters.
- ***Enhancing Biological Oxygen Demand and Suspended Solids Removal Prior to the Energy Intensive Activated Sludge Process in Wastewater Treatment Plants*** – There are large amounts of energy associated with the secondary processes in wastewater treatment plants. This project would investigate a variety of alternatives that could enhance the removal of BOD and SS prior to the secondary treatment process.
- ***Recuperative Thickening of Anaerobic Digestion for Enhanced Gas Production-*** Gas production and sludge destruction may be enhanced by thickening and returning digested sludge to the anaerobic digester for

further treatment. This project would demonstrate the benefits and costs, economical and energy, of recuperative thickening for anaerobic digestion, and to evaluate the various approaches to recuperative thickening.

- ***Thermodynamic Evaluation of Advanced Water and Wastewater Treatment Technologies***-The operation of advanced water and wastewater plants are inadequately characterized for energy usage. In order to make energy efficiency improvements to advanced treatment process, the first step is to characterize the existing operations.
- ***Process Optimization: Using Advanced Controls, and On-line Instrumentation to Increase Capacity, Improve Performance and Improve Energy Efficiency***- Many existing water and wastewater treatment facilities in the U.S. were constructed in the 1970's and are now outdated or have reached maximum capacity. Many treatment facilities are in need of improvements in asset management plans, system consolidation and innovative solutions. This project aims to provide alternatives to costly construction upgrades and could also provide some security enhancements.

6. Sustainability

Providing for a sustainable energy future is a critical area for research. Development of policies and practices that preserve and enhance the environment and provide for the energy needs of future generations is an important goal.

The opportunity to investigate and quantify energy applications to offset increased demand, reduce non-point pollution, reduce cross-media pollution, and avoid impacts (e.g., greenhouse gas emissions from energy use and methane production, groundwater basin salinity) should be a high priority. Natural systems offer low-energy solutions for pollution control. Sustainable energy sources are a long-term goal.

Table 2.7 summarizes the research needs related to the primary research area of sustainability and project ideas that could contribute to addressing the needs. Many of the project ideas that are presented in the primary research area of optimization could also be included in the sustainability research area to meet the need of improving existing technologies because of the outcome of reducing energy use and cross media pollution when processes are improved.

Table 2.7: Sustainability Research Needs and Potential Solutions

SUSTAINABILITY	
Needs	Potential Solutions
Cross- media pollution and impact reduction (greenhouse gas emissions from energy use and methane production, groundwater basin salinity)	#5: Conversion of Digester Gas to Liquefied Natural Gas and Liquefied Carbon Dioxide #14: Cost Effective Digester Gas Cleanup for Advanced Power Generation #30: Peracetic Acid Pilot Study for Effluent Disinfection
Water use efficiency including conservation policy and practice and water recycling	#19: Development of Customized Pretreatment and Diversion Programs
Water reuse policy and practice	#34: The Cost and Value of Recycled Water
Aquifer storage and recharge	#35: Development of Recycled Water Quality Indicators for Reclaimed Waters Use for Groundwater Recharge
Stormwater management and nonpoint source pollution control	#41: Ballasted Flocculation
Using and improving existing technology or best available technology	#10: Energy Consumption of UV and Chlorine/Sodium Hypochlorite Disinfection #12: Use of Membranes for Treatment of Biosolids Processing Recycles #18: Development of Anaerobic Treatment Technologies for Municipal Wastewater Treatment
Reducing chemical usage	#32: Energy-Efficient, Carbon-Efficient Advanced Wastewater Treatment for Natural Systems #41: Ballasted Flocculation
Methods to facilitate adoption of emerging technologies	*

The following are examples of research project descriptions developed at the workshop that will help provide solutions to the research needs identified in the area of *Sustainability*.

- ***Energy-Efficient, Carbon-Efficient Alternative Advanced Wastewater Treatment-*** The objective of this study would be to demonstrate and quantify the energy efficiency and additional environmental benefits of

advanced natural systems for primary, secondary and tertiary treatment. The project would also demonstrate water reuse, biogas recovery, power generation, and nutrient recovery and recycling. (move from advanced treatment processes to sustainability)

- ***Development of Recycled Water Quality Indicators for Reclaimed Waters Used for Ground Water Recharge-*** Reclaimed water is a significant resource and is utilized by many agencies in California to recharge groundwater supplies. The most common recharge method is using either secondary or tertiary treated water in spreading basins. This project would develop a scientifically based quality indicator for judging suitability of reclaimed water for groundwater recharge, protect public health, and suggest proper treatment levels needed to meet proposed quality indicators. (move from societal and institutional to sustainability)
- ***Ballasted Flocculation-*** Research is needed to evaluate the design, efficiency and energy consumption of ballasted flocculation systems and how it can alleviate the energy “workload” of the secondary system, particularly during wet weather.

7. Decentralization

There is considerable discussion within the water and wastewater sectors regarding the benefits and drawbacks of decentralization of water and wastewater treatment. In the drinking water area, decentralization is being considered as a potential means of complying with the increasingly stringent requirements of the Safe Drinking Water Act. For example, the difficulty in maintaining the quality of water in older water distribution systems has raised the question regarding the benefits of placing point-of-use or point-of-entry devices in neighborhoods or in homes. In the wastewater area, small packaged wastewater treatment plants and local reuse of the product water can be cost-effective, particularly in new developments. Distributing industrial pretreatment or stormwater treatment in the watershed has energy implications (and potential savings). The potential for decentralization to generate energy savings or costs is little understood.

Example projects identified in the area of *Decentralization* include:

- ***Explore Options for Decentralized and Small-Scale Wastewater Treatment Systems that are Energy Efficient-*** A large percentage of energy used for wastewater management is used to transport wastewater to centralized wastewater treatment plants. This project aims to develop a model to predict energy use and the cost of capital and operation and maintenance of a variety of decentralized wastewater collection and treatment systems.

- **Barriers to Using Fine Pore Aeration Systems at Smaller Treatment Plants-** Aeration is the most energy intensive aspect of secondary treatment. Typically 40 to 60% of the power consumption at a treatment plant is consumed by aeration. The project's objective is to determine which barriers (economic, technical or regulatory) prevent small plants from utilizing high efficiency fine pore aeration systems.
- **Recovery and Use of Digester Gas at Small Wastewater Treatment Plants.** This research project is focused on increasing recovery of digester gas at small wastewater treatment plants. The project's objective is to determine barriers that prevent small wastewater treatment plants from recovering more energy from digester gas.

8. Total Energy Management

The concept of Total Energy Management (TEM) represents the integration of the true energy cost of the anthropogenic water cycle (water supply, conveyance, treatment, distribution, wastewater treatment, and reclamation). Studies to understand and optimize the use of energy in the provision of water and wastewater service to society are needed. TEM implies the incorporation of energy use, water and wastewater stewardship, and environmental values in decisions related to these services. TEM considers both direct and indirect energy use related to water and wastewater service provision including chemical use and manufacture, transportation costs, and residuals handling and disposal costs, for example.

Table 2.8 summarizes the needs for the primary research area of *Total Energy Management* and project ideas that could contribute to addressing the needs.

Table 2.8: Total Energy Management Research Needs and Potential Solutions

TOTAL ENERGY MANAGEMENT	
Needs	Potential Solutions
"Energy Star" or ISO certification with incentives	#2: Water and Wastewater Treatment Plant Energy Efficiency Achievement Program
	(continued)

Table 2.8 (Continued)

Needs	Potential Solutions
Baseline and self-evaluation criteria	#8: Development of a Utility Energy Index to Assist in Benchmarking of Energy Management for Water and Wastewater Utilities #26a: Guidance Manual: Protecting Treated Water Quality While Reducing Energy Costs #26b: Guidance Manual: Protecting Distribution System Water Quality While Reducing Energy Costs
Direct energy use related to water and wastewater service provision	#36: Thermodynamic Evaluation of Advanced Water and Wastewater Treatment Technologies
Indirect energy use related to water and wastewater service provision	*
Whole system analysis methods	#17: Estimation of Embedded Energy in Water #27: Energy Consumption for Potable Water Conveyance and Treatment in Southern California Region
Real time energy monitoring	*
Demand management and integrating peaks	#39: Digester Gas Storage for Improved Peak Power Management

The following are examples of research project descriptions developed at the workshop that will help provide solutions to the research needs identified in the area of *Total Energy Management*.

- ***Water and Wastewater Treatment Plant Energy Efficiency Achievement Program-*** Typical water or wastewater treatment plants may be able to reduce their energy costs by up to 30% or more by instituting energy efficiency programs. This project strives to establish a statewide Energy Efficiency Achievement Program for the water and wastewater industry. This program will set energy reduction goals and is to be managed by an unbiased third party group to review and place “stamp of approval” for energy efficiency operations.
- ***Development of a Utility Energy Index to Assist in Benchmarking of Energy Management in Water & Wastewater Utilities-*** The development of an energy index will allow water and wastewater utilities to evaluate their internal energy management efforts and provide a

framework for dialogue between utilities. This project aims to provide useful index/indices to which the results of a company's energy strategy can be measured and compared to internal benchmarks and key indices of other utilities. (move from sustainability to TEM)

- ***Guidance Manual: Protecting Treated Water Quality While Reducing Energy Costs*** - Many energy management techniques have the ability to negatively impact the quality of water within the treatment facility. This project addresses water quality risks at the treatment facility associated with energy management practices.
- ***Guidance Manual: Protecting Distribution System Water Quality While Reducing Energy Costs*** – Many energy management techniques have the ability to negatively impact the quality of water within the distribution system. This project addresses water quality risks in the distribution system associated with energy management practices.
- ***Digester Gas Storage for Improved Peak Power Management***- Diurnal storage of digester gas can provide improved power production at peak times for plants with turbines and/or fuel cells. For plants that are considering turbines and/or fuel cells, this project will look at ways to optimize designs for peak shaving-optimization to improve return on investment and value to the grid of digester gas.

CHAPTER 3

CONCLUSIONS AND RECOMMENDATIONS

This roadmap contains general and specific areas of research interest with potential for generating energy and cost savings. Eight general areas of research were identified including advanced treatment processes, desalination, energy generation and recovery, societal and institutional issues, optimization, sustainability, decentralization, and total energy management. A total of 44 specific projects were identified and described within these eight areas. A detailed matrix ([Appendix B](#)) includes project titles, budget estimates, schedules and general rankings by potential savings, likelihood of success, and timeliness.

While all identified projects were viewed as having potential value, several projects received the highest rankings for potential savings, likelihood of success and timeliness. These included:

- Review of International Desalination Research
- Dual Fueled Backup Generators (BUGS) for Reliability and Peak Shaving
- Barriers to Using Fine Pore Aeration Systems at Smaller Treatment Plants
- Energy Efficient, Carbon Efficient Advanced Wastewater Treatment for New and Retrofitted Natural Systems

Based upon an informal “dot voting” method the following projects received significant support from the expert workshop members:

- Water and Wastewater Treatment Plant Energy Efficiency Achievement Program
- Development of a Utility Energy Index to Assist in Benchmarking of Energy Management in Water & Wastewater Utilities
- Cost Effective Digester Gas Cleanup for Advanced Power Generation
- Gas Enhancement During Anaerobic Process of Sewage Sludge by Co-digestion of Organic Solid Wastes
- Zero Liquid Discharge for In-land Desalination
- Cost and Value of Recycled Water

The identified projects represent estimated potential funding opportunities of nearly \$25,000,000 for the Commission/AwwaRF research partnership. These projects and areas of research represent a pool of potentially fundable work that can generate energy and cost savings for California and for the drinking water and wastewater community.

APPENDIX A IDENTIFIED RESEARCH PROJECTS

1. Review of International Desalination Research

Description of Issue: Inefficiency in research and development efforts results from lack of knowledge of others development efforts. This has been overcome by AWWA and the Bureau of Reclamation's publication of previous United States desalination development efforts into a 12 CD-ROM database called DESALNET™. However, much of research and development of brackish and seawater development have been in other parts of the world. Large seawater desalination plants (15 MGD) have been operating for over 15 years in Saudi Arabia. Additional, international desalination research organizations have developed advanced desalination techniques

Benefits for Water and Wastewater Community: Conducting a literature review would eliminate unnecessary funding for research projects that duplicate previous work.

Objective: The project objective would be to develop a reference document containing current research and development efforts of the international desalination community.

Recommended Funding: Total project cost is \$70,000.

Potential Controversial Issues: Obtaining detailed information from some of the foreign research organizations can be difficult. In that case, document of published information will be used.

Background:

International desalination has a much longer operating history than in the US. For example, a 15 MGD seawater desalination plant has been continuously operating in the Middle East since 1985. Only recently has the US considered major seawater desalination facility (25 MGD) for a permanent supply.

Research Approach:

Several international and U.S. research organizations are conducting research on improving desalination efficiency. Seawater desalination has extensive worldwide operating experience, especially in the Middle East. What can be learned from international experience to guide further development in the U.S.? Identify these efforts to compare to other desalination research in order to identify where best to focus AwwaRF efforts.

The project approach would include:

1. Developing a list of all international research programs
2. Developing contacts within those organizations
3. Compiling reference documents from those organizations
4. Providing a report detailing the major research efforts of those organizations, their research goals, and a listing of current research efforts.

2. Water and Wastewater Treatment Plant Energy Efficiency Achievement Program

Description of Issue: One industry key to economic development is the availability of municipal water and wastewater services. Clean drinking water and adequate wastewater treatment capacity are essential to a region's economic growth, and by extension any electric load growth. Electricity is the second largest operating cost for most water and wastewater systems and the water and wastewater industry faces unprecedented demands from new environmental regulations. This industry consumes an estimated 5% of California's energy use. The EPRI Municipal Water and Wastewater Program has shown that many plants can achieve 10-30% reduction in energy use by instituting energy efficiency programs.

Benefits for Water and Wastewater Community: A typical water or wastewater treatment plant may be able to reduce their energy cost by up to 30% or more by instituting energy efficiency programs. EPRI has found that energy efficiency savings in the water and wastewater industry are mainly achieved by analyzing and improving operational and process systems and less on conventional approaches such as motor efficiency improvements. A state-wide energy efficiency achievement program could target this specific industry to provide a "seal of approval" for those treatment facilities that have been studied and shown to achieve an energy optimum performance.

Objective: The project objective would be to establish a state-wide Energy Efficiency Achievement Program for the water and wastewater industry. This program would set energy reduction goals and be managed by an unbiased third party group to review and place a "seal of approval" for energy efficiency operations.

Recommended Funding: Total project cost is \$250,000 per year.

Past and Ongoing Research: Past activities by AwwaRF, WERF, AWWA, and WEF (benchmarking studies and databases) have not focused on energy management. This approach would focus on recognition of energy efficiencies. Past EPRI activities have looked at assessment but not recognition. This concept is illustrated by the "Energy Star" Program.

Background:

EPRI has conducted energy process audits at water and wastewater facilities for over 10 years. Many of these audits have concluded that energy efficiency opportunities could be achieved by making process modifications. In many cases, the plant personnel were reluctant to make these changes since they were taking a risk with the change and they did not fully understand the long term benefits in energy reduction. There was no recognition for plant personnel and any perceived risk far outweighed the potential benefit. By establishing a state-wide achievement program, treatment plant personnel will more eagerly embrace energy efficiency efforts and will be recognized on a level playing field with their peers.

Research Approach:

The project scope would include the following:

1. Establish an energy efficiency team to identify, obtain, and prepare proper benchmarked treatment unit process and energy information suitable for use in this program. This team would develop criteria and methods for treatment plant certification.
2. Develop marketing information to encourage water and wastewater plants in the state to participate in this program and to recognize those plants that have been certified as energy compliant.
3. Conduct plant reviews for those plants participating in the program.
4. Prepare an annual report to the state detailing results from the program.

3. UV Optimization Guidance Manual

Description of Issue: UV disinfection is a relatively new treatment technology, particularly to the drinking water community. As a new technology, most water and wastewater suppliers have only limited direct experience with its advantages, disadvantages and operating peculiarities. Given the lack of existing regulatory guidance, there is an understandable reluctance to adopt the technology even if it is economically advantageous to do so. Designers of UV systems face a number of choices on lamp design, reactor type, design dosage and target organism, sleeve materials, system electronics, and UV sensors. Regulatory guidance on these issues will be released in draft form for comment sometime in mid-2003. As more water and wastewater facilities employ UV technologies, guidance on how to optimize UV systems will result in energy efficiency savings.

Benefits for Water and Wastewater Community: A typical water or wastewater treatment plant, switching to UV disinfection from chemical disinfection may experience a rise in overall plant energy use because the technology uses more energy than chlorination; however, overall O&M may decrease. Wastewater experience shows that plant personnel greatly embrace UV technology because it eliminates the complexities associated with dechlorinating wastewater and handling large quantities of chlorine. Another

important benefit to wastewater operations that switch from chlorination/dechlorination to UV disinfection would be the elimination of a significant number of liquid chlorine storage sites. Liquid chlorine is stored in containers under pressure, and leaks of the chemical have led to massive evacuations in numerous places throughout the country. UV disinfection eliminates this threat, which presents tremendous logistical issues of emergency management teams and other local officials.

A guidance document would provide engineering firms, water and wastewater plants, and state regulators with the knowledge necessary to design and operate optimized UV systems.

Objective: The project objective would be to develop a UV optimization guidance manual that can be used by planners, engineers, water and wastewater treatment plant operators, and energy managers to provide objective guidance for the successful implementation of UV technology in an energy efficient manner. This would expand upon the existing guidance manuals available to improve process equipment and focus on efficient use of UV by operating staff.

Recommended Funding: Total project cost is \$160,000.

Staff Comments: This project may not be necessary because of other ongoing research. NYSERDA is currently funding a project to develop tools for drinking water utilities to optimize the application of UV disinfection by 1) quantifying the impact of operational factors on the efficiency and performance of UV lamps, 2) developing rational approaches for selecting lamp aging factors for sizing UV systems 3) developing rational approaches for selecting UV system redundancy and backup power in response to system failure, 4) evaluating the performance of commercial UV lamp/ballast assemblies, and 5) optimizing drinking water UV reactor validation. The USEPA is in the process of developing a guidance manual for UV disinfection. The National Water Research Institute recently updated a publication entitled, *Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse* (NWRI 2003)

Background:

Water and wastewater suppliers in the state of California face the challenge of providing their essential services at lower costs, while meeting more stringent regulations and the rising demands of a growing population. Such opposing goals can only be met by adopting more advanced treatment technologies that can provide a higher level of treatment at lower costs. One very promising technology is ultraviolet light disinfection, for both treated wastewater and drinking water. The application of UV technology has quickly spread to the wastewater industry, and is gaining acceptance also in the drinking water industry. As a newer technology, many design and operational parameters have been established on a conservative basis. This has lead to a less than optimum operating condition causing excess cost and energy usage. Now that this

technology is maturing, an unbiased assessment of UV system operation can be made to optimize its use.

Research Approach:

The project scope would include the following:

1. Survey of existing UV installations to determine design features (lamps, channels, etc.) as well as operational practices (power usage, lamp replacement), and operating data
2. Development of UV Application Guidance Manual to include:
 - A summary of existing and emerging technologies
 - Operating data from operating plants
 - Recommended design criteria
 - Power quality and usage requirements
 - Testing and performance evaluation
 - Operational procedures
 - Optimization guidelines
3. The development of case studies from existing facilities
4. A final workshop.

4. Dual Fueled Backup Generators (BUGS) for Reliability and Peak Shaving

Description of Issue: Water and wastewater facilities frequently have a need for complete backup electrical power supplies to insure reliability of their operations. In many cases, redundant electrical supplies are required by law. The U.S. Environmental Protection Agency allows wastewater facilities to consider redundant utility feeds or dedicated generators to serve this purpose. Currently, some existing sewer pump stations are being considered as candidates for backup power because of decreased tolerance for spills. Additionally, with the recent rolling blackouts and documented lack of planning of California's future electric systems, redundant utility feeds are no longer considered by some to be adequate, and generators are being considered for the additional redundancy. Additionally, wastewater facilities are not eligible to be exempted from rolling blackouts. The technology exists to convert diesel generators to operate on natural gas with diesel pilot ignition.

Benefits for Water and Wastewater Community: Dual fuel backup generators (BUGs) could provide backup power systems that provide more in-house control than dual utility feeds or continuous duty. Additionally, dual fuel BUGs are economically superior to diesel BUGs since existing assets can be used in many cases. Dual fuel BUGs will not only reduce the risk of loss of electrical supply, but can also provide a means to avoid electrical energy costs by operating as a peak shaving generator. Thus, a dual fuel BUG can generate revenues and offset the installation costs of the backup electrical supply system. Additionally, all Western regional electrical system customers benefit from large electrical customers removing their electrical load from the grid during peak electrical

consumption and cost periods. While this equipment would typically experience 10 to 20 times more run hours per year, operating a diesel engine as methane fired dual fueled unit causes considerably less wear and tear on the equipment per hour.

Objective: The objective of this project would be to evaluate methane injection systems, and determine whether the air pollution control systems required to meet Best Available Control Technology (BACT) can be optimized to reduce installation costs. This project should also determine the cost effectiveness of this technology (e.g., increased O&M costs, changes in the life of the equipment).

Recommended Funding: \$500,000

Background:

In the past, backup generation systems were considered to be a large capital cost, with ongoing expenses. Because of air pollution restrictions on diesel fired generators, they have no ability to generate revenues and can only operate for a limited number of hours per year. Within the last few years, various technologies have been developed that allow conversion of diesel generators to burn a mixture of 80% + methane and < 20% diesel fuel. These systems can be installed to meet California's air pollution requirements for peak shaving systems and possibly continuous duty. In addition to the cost savings to plant owners, this will provide valuable capacity during periods of peak load demand and would reduce the cost of all electrical consumers.

Research Approach:

This project would be to evaluate methane injection systems, and determine whether the air pollution control systems required to meet BACT can be optimized to reduce installation costs. This project should also determine the cost effectiveness of this technology (e.g., increased O&M costs, changes in the life of the equipment). To meet these objectives, the project tasks would include:

1. Research costs of various dual fuel conversion systems and associated air pollution control systems.
2. Research cost of installation and maintenance cost for various dual fuel systems.
3. Determine most cost effective system based on study results.
4. Issue RFP to convert an existing generator with a design build performance specifications to encourage competition at obtainable performance levels. Use an evaluated bid process with price being a major factor to select the design builder.
5. Confirm installation cost, operational costs revenues, and operational parameters over a three (3) year monitoring period. Determine systems cost effectiveness.
6. Issue report and publish paper.

5. Conversion of Digester Gas to Liquefied Natural Gas (LNG) and Liquefied Carbon Dioxide (LCO₂)

Description of Issue: Often, anaerobic digester gas from wastewater treatment plants (WWTP) is not reused due to insufficient recovery, capacity, economics, or air pollution limits. Flaring of this “excess” gas wastes the fuel value of the gas and adds air pollutants and green house gases to the atmosphere.

Benefits for Water and Wastewater Community: The technology is now being developed so that small gas liquefaction systems (i.e., 5,000 to 10,000 gallon per day) can be economically installed at WWTPs that are 30 MGD or larger to convert this waste gas stream into a clean vehicle fuel and commercial liquid CO₂, providing the treatment plant a revenue stream.

Objective: The objective would be to install the first digester gas liquefaction system to demonstrate the technology’s technical and economic viability.

Recommended Funding: Total project cost is projected at \$7,000,000. Requested funding is \$3,000,000 with matching funds of \$4,000,000.

Background:

Digester gas is a source of NOX, CO₂, SOX and particulates when flared. Many WWTPs utilize this gas to fuel on-site power generation systems. However, due to air pollution restrictions, cost to install and operate power generation systems, and current wholesale electric buy back rates, electrical generation is not always viable. Additionally, large WWTPs may produce enough air pollutants to be considered a “major source” of air pollutants. Therefore, they are strongly encouraged to reduce their air emissions. This liquification process would convert these pollutants into a certified clean vehicle fuel, LNG, and a commercial product, liquid CO₂. Other pollutants, such as SOX would be scrubbed from the gas and disposed.

Research Approach:

The project scope would include the following:

1. Determine the actual cost to install these two (2) liquification systems, assuming 5,000 to 10,000 gallons per day of LNG flow.
2. Determine the facilities’ O&M costs
3. Determine the facilities’ long term viability by monitoring all costs and revenues including any marketing requirements.
4. Determine waste streams and their effects on the WWTP and the environment.
5. Compare LNG production to onsite energy production on economic and environmental grounds.
6. Issue report.

6. Catalytic Advanced Oxidation Systems

Description of Issue: The concern over emerging contaminants passing through membrane processes prompted water agencies to test for the presence of organic contaminants of public health concern (pharmaceuticals, endocrine disruptors, disinfection by-products, etc.) in feed and product water. Current contaminants of concern include n-nitrosodimethylamine (NDMA), methyl tert butyl ether (MTBE), and 1,4 dioxane. Current research has shown that these compounds are released in the environment and pass through wastewater treatment systems. Advanced Oxidation Processes (AOPs) can remove these compounds. The use of catalytic AOPs provide a particularly appealing solution, as they offer an energy efficient method of organic compound removal compared to conventional ultraviolet (UV)/hydrogen peroxide or UV/ozone treatment. New catalysts that are particularly attractive include nitrogen, carbon or other substituted titanium dioxide (TiO_2) minerals capable of producing hydroxyl free radicals from water using visible light ($>400\text{nm}$) photons.

Benefits for Water and Wastewater Community: This project could help water utilities achieve efficient organic contaminant removal with reduced energy requirements.

Objective: The project objective would be to develop a more energy efficient AOP reactor to remove the organic contaminants that pass through the reverse osmosis (RO) barrier, resulting in an energy savings over conventional solution phase AOPs.

Recommended Funding: \$150,000

Background:

Currently, commercial scale advanced oxidation processes (AOPs) designed to remove organic contaminants (e.g. NDMA, 1,4-dioxane, MTBE, etc.) from water are solution phase treatments that rely on either direct oxidation by ultraviolet (UV) photon irradiation, oxidation by hydroxyl free radicals formed by UV irradiation of hydrogen peroxide, or ozone added to the water under treatment. UV light is generated by mercury vapor gas discharge lamps. These lamps are an energy-intensive process. Moreover, components present in the water that scatter or absorb UV photons may drastically reduce the efficiency of treatment. By contrast, AOP may be carried out on surfaces coated with semiconductor catalysts such as titanium dioxide (TiO_2) photoactivated by irradiation with UV light. In this photocatalytic process, photons create a charge separation on the catalyst surface via the photoelectric effect. Hydroxyl free radicals are formed from water molecules near the catalyst surface, and as with solution-phase oxidation, these radicals oxidize the organic compounds. The hydroxyl radical formation near the catalyst surface is high compared to formation in free solution, so oxidation near the catalyst surface is far more efficient. Additionally, the

catalyst surface may be directly deposited on the light source and photoactivated from below; in this configuration the photon density at the catalyst surface is high, and oxidation is immune to light scattering or absorption by components of the water under treatment. Titania-based catalytic oxidation systems have already been incorporated into self-cleaning window glasses, air purification systems, and have been used to remove volatile organic contaminants (VOCs) from groundwater. Although titania, the more commonly applied catalyst, requires UV light for activation, catalytic materials (such as nitrogen-substituted TiO_2) have recently been discovered that use visible light wavelengths to generate hydroxyl free radicals from water. Visible light photons may be generated more efficiently than UV photons by conventional light sources (including sunlight), and thus it may be possible to build highly energy efficient AOP reactors using these new catalytic materials.

Research Approach:

Efficiency of organic contaminant removal by catalytic AOPs would be tested at the bench scale or the pilot scale (2 – 30 gallons per minute). Although UV-irradiated systems will be considered, preference will be given to reactor designs using catalysts capable of utilizing longer wavelengths of light (e.g., nitrogen substituted TiO_2), and although designs utilizing auxiliary oxidants (e.g., ozone or hydrogen peroxide) will be considered, preference will be given to designs capable of generating hydroxyl free radicals directly from water. Reactors may be powered either by conventional light sources (e.g. incandescent lamps, fluorescent lamps, gas discharge lamps, light-emitting diode arrays, etc.) or by sunlight. In all cases, process efficiency will be defined by the energy to fully mineralize a unit mass of organic compound. No constraints on internal designs will be made (reactors include catalyst coated lamps, optical fibers, fluidized beads, etc.). The test compound list should represent a wide range of molecular classes if possible, and minimally must include NDMA, MTBE, and 1,4, dioxane. Removal efficiency of organic compounds, especially NDMA, should be considered at the nanogram per liter (part per trillion) level.

7. Advanced Treatment of Delta Water to Meet Future Regulations

Description of Issue: A large portion of California water utilities serving 21 million people use the San Joaquin Delta as a source of drinking water. The water quality is variable and presents challenges to utilities in meeting current and future drinking water regulations, particularly disinfection and disinfection by product (DDBP) regulations. Conventional and advanced treatment technologies will likely need to be replaced with more sophisticated treatment technologies that also tend to be more energy intensive.

Benefits for Water and Wastewater Community: This project will benefit the water districts that serve 21 million consumers in California.

Objective: This project would determine the best means of optimizing advanced drinking water treatment technologies for energy utilization on the demonstration scale. It would examine UV, membranes, ozone and multiple disinfectants.

Recommended Funding: The total project cost is \$1,500,000. Requested funding is \$500,000 to match with \$1 million from the water districts, EPA and AwwaRF.

Past and Ongoing Related Research: A blue ribbon paper study has been done by CUWA to determine water quality thresholds for Delta water. What are missing are studies that consider practical operating considerations and high degree of variability in Delta water. Existing studies also do not examine synergistic affects of multiple process technologies.

Background:

This research would specifically address the unique and variable source water of the Sacramento-San Joaquin Delta and the effectiveness of various treatment options. The 21 collaborating water districts deliver drinking water from the Delta to over 2 million Bay Area residents. Many of these water districts face a shared need to understand the feasibility and cost effectiveness of emerging technologies in order to make investment decisions while continuing to deliver drinking water of the highest quality possible.

Research Approach:

The objective of this proposed research project would be to complete studies in advanced drinking water treatment technology and provide investment and operational guidance in the use of these technologies to utilities that use Delta water as a source of supply. Applied research would determine treatment technology effectiveness in disinfection, minimization of disinfection byproduct formation, treatment of emerging contaminants, and minimization of taste and odors in treated water. Research would be performed at the bench scale and pilot scale level. Testing could be conducted at existing treatment facilities operated by participating utilities. To accomplish this, transportable pilot and demonstration scale equipment could be procured to test source water at various locations. The bench and demonstration scale testing would develop energy consumption data and overall costs associated with various proposed process configurations under a wide variety of water quality conditions.

The duration of the testing should cover the full range of variability in Delta water including seasonal variations and geographic location. Present and future water quality conditions of Delta source water will be considered. The research must be specific enough to address the participating water agencies' respective needs, yet general enough to provide broader benefits to other metropolitan areas utilizing similar source water.

8. Development of a Utility Energy Index to Assist in Benchmarking of Energy Management for Water and Wastewater Utilities

Description of Issue: Generally water and wastewater utilities do not have a standard mechanism that allows them to measure and compare the effectiveness of energy efficiency efforts within the company or against other company's similar efforts. Complex gas and electric rate structures, combined with difficulty in identifying the necessary metrics for such comparisons, complicate efforts to develop useful indices. Differences in infrastructure configuration further complicate the ability of utilities to compare energy conservation and cost reduction efforts.

Benefits for Water and Wastewater Community: The development of the index will allow water and wastewater utilities to evaluate their internal energy management efforts and provide a framework for dialog between utilities.

Objective: The objective of the project would be to provide useful index/indices to which the results of a company's energy strategy can be measured and compared to internal benchmarks and to key indices of other utilities.

Recommended Funding: \$250,000.

Background:

The AwwaRF report "Best Practices for Energy Management" (Jacobs, Kerestes, and Riddle 2003) identifies the value of a utility energy index to measure the progress of a company's efforts to reduce energy use and cost while providing a benchmark comparison to other like companies. The research project found that the data collected for such an index did not result in an index that could be used for comparisons with other companies. The recommendation of the project was that an index should be developed in a way that utilities could apply it internally and externally. Additional work was recommended to identify the best metrics and the measurement requirements to provide a useful utility index.

The Water Environment Research Foundation report *Improving Wastewater Treatment Plant Operations Efficiency and Effectiveness* (Eisenhart and Waltrip 1999) notes the importance of more advanced audits to evaluate how energy is being used and optimized. This index will supplement that advanced audit.

Research Approach:

Implement the recommendation from the "Best Practices for Energy Management" research project to further develop a utility index for internal use and possibly external comparison with other like companies.

9. Best Forecasting Tools for Predicting Water Demands for Energy Optimization of Pumping Plants

Description of Issue: Many water utilities have pumping plants that get electrical service from utilities that utilize various time driven electric tariffs. In order to effectively optimize pumping and treatment operations against these electric tariffs, a dependable and competent water demand-forecasting tool is essential. The water industry is currently investing monies into the development and installation of Energy Water Quality Management Systems (EWQMS), which compliment the existing SCADA systems. A water demand projection system serves as a cornerstone for the EWQMS installation. Currently a variety of different predictive programs using different methods exist that can perform water demand predictions. However, a single method or program has not been identified as the “best” choice for predicting water demands in water distribution systems. Being able to identify the “best” would provide water utilities a starting point for creating an optimal pumping operation of their water distribution system.

Benefits for Water and Wastewater Community: This project would provide the data necessary for water utilities to select the “best” water demand forecaster capable of making accurate water demand forecast. Water utilities could then use this tool to develop cost effective daily pumping operating plans. With this experience, a key piece of the EWQMS would be perfected and ultimately assist with the continued pursuit of such a system for all water utilities.

Objective: This research project would evaluate available methods and programs (tools) for making water demand predictions. It would identify criteria to rank each tool, and test and evaluate the performance of the forecasting tools that rank the highest to determine the “best” tool for making water demand predictions.

Recommended Funding: \$250,000.

Background:

Between 1995 and 1997 AwwaRF commissioned research on developing an Energy and Water Quality Management System (EWQMS). Two AwwaRF publications resulted: *Energy and Water Quality Management System* (Curtice, Jentgen, and Ward 1997) and *A Total Energy and Water Quality Management System* (Westin Engineering & Consulting 1999). The research identified significant opportunities for reducing operational costs while maintaining reliable, high-quality water service. One of the key modules identified was a water demand-forecasting tool. In 2002, the importance of electric load forecasting was identified as a best practice in the AwwaRF research project “Best Practices for Energy Management.” In order for water utilities to forecast their electric load, a reliable forecast of their water demands is essential.

Research approach:

The project scope would include the following:

1. Identify existing predictive software tools that could be used to predict water demands.
2. Identify predictable/forecasted indicators that influence water demands such as maximum and minimum air temperature, humidity, rainfall, wind, day of the week, season, and other predictable non- weather related factors that may influence water demands.
3. Test the significance of the identified indicators in making water demand projections.
4. Test the performance of the top ranked predictive tools at various utilities that represent various climates, customer cross-sections (e.g. resort communities, industrial communities, bedroom communities and agricultural communities), throughout the different seasons.
5. Summarize the performance of the tools and identify system requirements, strengths, and limitations.

10. Energy Consumption of Ultraviolet and Chlorine/Sodium Hypochlorite Disinfection

Description of Issue: As the price and technology for low pressure and medium pressure Hg UV are becoming more competitive, the need to benchmark the energy consumption of common alternatives is necessary. There is a need to quantify energy use and cost of UV and chemical disinfection systems to support analysis of the costs and benefits of the respective systems. Research is needed to survey the state-of-the-art UV systems and perform an integrated energy consumption and life-cycle costing analysis of UV systems, chlorine/sodium hypochlorite, and other similar systems.

Benefits for Water and Wastewater Community: Utilities could use the results of this project to support the analysis of the costs and benefit of disinfection systems, by using energy costs and consumption as a criteria for system selection.

Objective: The objective of the project would be to conduct an environmental, safety, and health impact analysis of low and medium pressure UV systems and chlorine based disinfection systems and to compile the information into a guidance manual.

Recommended Funding: \$100,000

Past and Ongoing Related Research: Related research has been performed by EPRI and various wastewater treatment facilities but not captured in a guidance manual.

Potential Controversial Issues: Proprietary cost information from suppliers of chlorine and sodium hypochlorite, etc., could be hard to obtain. Global commodity pricing may make analysis difficult.

Background:

The price and technology for low and medium pressure UV systems are becoming more competitive with chlorine/sodium hypochlorite disinfection. Quantitative cost and benefit information, including energy costs and consumption, would help water and wastewater utilities evaluate disinfection alternatives. Chlorine dioxide pre-oxidant studies have been performed by Contra Costa Water District (CCWD.)

Research Approach:

The research would include the following tasks:

1. Review available life-cycle costing or cost comparison documents.
2. Perform survey and literature review to update available cost element database.
3. Scan and select appropriate life-cycle costing model, e.g., NPV, ROI, etc.
4. Identify and quantify intangible benefits, e.g., environmental, health and risk assessment variables, to support the analysis
5. Solicit wastewater UV users to participate in the review and, if possible, benchmark the analysis results.

11. Development of In-Line, Continuous Thermal Hydrolysis for Improving Municipal Biosolids Digestion

Description of Issue: Anaerobic digestion of municipal biosolids generated from wastewater treatment results in generation of digester gas (typically used for co-generation) and reduction of the biosolids to reuse/disposal sites. High temperature hydrolysis can significantly improve the digestion process, increase gas production and energy recovery, efficiently utilize waste heat, and improve the viscosity of the biosolids. The improved viscosity allows the digesters to operate at higher solids content, thus further reducing mixing and heating energy requirements. The thermal hydrolysis systems currently employed consist of a batch process requiring, steam injection, multiple tanks (typically three in series) and high operating pressures. A continuous, in-line thermal hydrolysis can provide similar benefits at a fraction of the cost.

Benefits for Water and Wastewater Community: The benefits of the process include: 1) increase in digester gas production resulting in additional energy recovery potential; 2) reduction of mixing and heating energy requirements; 3) recovery of the co-generation waste heat for thermal hydrolysis; and 4) improved dewaterability of the residual solids and reduction of the biosolids mass which reduces the biosolids volume to disposal and resulting truck traffic and fuel use.

Objective: This project would develop and apply continuous thermal hydrolysis, establish optimal operating parameters, establish digestion enhancement and increase in digester gas and energy production, evaluate improvements in dewaterability of the biosolids, and establish the cost savings and environmental benefits associated with the process.

Recommended Funding: The total project cost is estimated at \$600,000 for the pilot system development, field installation, testing, and analysis of the results. The funding level could be revised based on the pilot system size and/or operating duration.

Background:

Previous work, using batch steam hydrolysis, has shown that thermal hydrolysis can improve digestion of biological biosolids, resulting in 20% to 50% increase in gas production, significant biosolids mass reduction, and about 10 percentage point improvement in dewatered biosolids cake. Typical batch steam hydrolysis consists of a three step process requiring multiple tanks and pumping systems. The batch steam hydrolysis also requires operating temperatures of over 300 degrees F and operating pressures in the range of 150 psi. The cost and complexity of thermal hydrolysis can be substantially reduced by developing a continuous thermal hydrolysis system, operating at lower operating pressures.

Research Approach:

The project scope would consist of the following:

1. Develop the system configuration
2. Conduct bench scale testing to establish the operating parameters
3. Select treatment plant site for pilot testing
4. Build and install the pilot unit for continuous thermal hydrolysis
5. Based on operating results establish the optimum pressure/temperature points
6. Conduct cost-benefit analysis for the system.

12. Use of Membranes for Treatment of Biosolids Processing Recycles

Description of Issue: The recycles generated from biosolids treatment processes contain high concentrations of ammonia, phosphorus, alkalinity, total dissolved salts, and hardness. Presently, this recycle stream is returned to the treatment works and imposes a significant load (i.e., 1/3 of the total ammonia load) on the treatment facilities. Since ammonia causes effluent toxicity, most plants are required to nitrify the ammonia which significantly increases the aeration air and air blower power demands. Treatment of other constituents, if required by discharge permit, would further increase treatment process energy and/or chemical requirements. Separate biosolids processing recycles side-stream treatment, using biological processes, are not proven to be cost effective due to insufficient carbon source present in the recycle stream. Addition of supplemental carbon source (i.e., methanol) has been expensive and not economically feasible. Physical/chemical treatment processes such as use of membranes, distillation, ammonia stripping/neutralization options can be utilized for treatment of these side streams and would result in treatment cost savings while recovering these valuable nutrients.

Benefits for Water and Wastewater Community: The benefits of the process include: 1) reduction of the treatment energy costs, 2) reduction of treatment tankage and associated site space requirements; 3) reduction of the shock loading to treatment facilities; and 4) recovery of the beneficial nutrients that can be used as fertilizers, thus, offsetting the energy usage required for fertilizer manufacturing.

Objective: This project would develop and test membrane systems for treatment of biosolids processing recycles, establish operating parameters, identify energy savings and other environmental benefits, and establish cost-benefit of the technology.

Recommended Funding: The total project cost is estimated at about \$700,000 for the pilot system development, field installation, testing, and analysis of the results. The funding level can be revised based on the pilot system size and/or operating duration.

Background:

Previous work conducted with membranes indicates that membrane technology (MF/UF) can be applied to high solids streams such as activated sludge (membrane bioreactor) and primary effluent. The work done with food waste and animal waste also indicates that membrane technology can be applied directly to digested animal and food waste with high solids content. The biosolids processing recycles, typically contain a fraction of the solids compared to digested animal and food waste. The application of MF/UF as the first step, followed by RO can concentrate the constituents in the biosolids processing

recycles. This process would make recovering the beneficial nutrients through distillation and or physical/chemical processes more feasible.

Research Approach:

The project scope would consist of the following:

1. Develop the system configuration for the biosolids processing recycles membrane treatment system
2. Conduct bench scale testing to establish operating parameters
3. Select treatment plant site for pilot testing
4. Build and install the pilot unit
5. Based on operating results establish the optimum membrane design and operating parameters
6. Conduct cost-benefit analysis for the system.

13. Development of High Solids, Vertical, Plug Flow Anaerobic Digestion

Description of Issue: Anaerobic digestion of biosolids generated from wastewater treatment results in generation of digester gas (typically used for co-generation) and reduction of the biosolids mass to reuse/disposal sites. The digesters currently used operate with solids content typically in the range of 4% to 6% and require continuous mixing and heating. An unmixed or partially mixed, vertical, plug flow digester operating at a solids content of 12% to 20% substantially reduces the digester volume as well as mixing power and heating energy requirements. Since biosolids management costs can be up to ½ of the wastewater treatment facilities cost, this technology can significantly reduce the overall wastewater management costs and energy requirements.

Benefits for Water and Wastewater Community: The benefits of the process include: 1) Reduction of the digester volume by a factor of 2 to 5; 2) reduction of the biosolids mass to digesters and associated pumping power and heating energy requirements; 3) reduction or elimination of the mixing requirements, further reducing power demands; and 4) improved net energy recovery from digestion due the reduction in energy requirements for digester operation.

Objective: This project would develop and test high solids, vertical, plug flow digester; establish optimal operating parameters and mixing/heating needs, establish improvements in net energy recovery, evaluate improvements in dewaterability of the biosolids, and establish the cost savings associated with the process.

Recommended Funding: The total project cost is estimated at \$850,000 for the pilot system development, field installation, testing, and analysis of the results. The funding level can be revised based on the pilot system size and/or operating duration.

Background:

Previous work, using plug flow digestion for food waste, has shown that plug flow digestion can be operated at elevated solids content. These digesters have been operated at solids content in the range of 20% to 25% in both thermophilic and mesophilic temperature ranges. The quality of the biosolids, however, is significantly different than food waste. The high biosolids solid content proposed requires investigating options to improve viscosity of the biosolids feed to digester, evaluation of ammonia toxicity potential, developing optimal diameter to height ratio, and methods/equipment for heating and transferring the biosolids cake to the digester.

Research Approach:

The project scope would consist of the following:

1. Develop the system configuration for the high solids, vertical, plug flow digester.
2. Conduct bench scale testing to establish operating parameters.
3. Select treatment plant site for pilot testing.
4. Build and install the pilot unit.
5. Based on operating results, establish the optimum feed biosolids solids concentration, heating method, optimal diameter to depth, and residence time.
6. Conduct cost-benefit analysis for the system.

14. Cost Effective Digester Gas Cleanup for Advanced Power Generation

Description of Issue: Wastewater treatment plant digester gas contains sulfur, halogenated hydrocarbons, and siloxanes that are harmful to post combustion emission control equipment. This limits the use of the gas or results in higher, uncontrolled air emissions.

Benefits for Water and Wastewater Community: Use of digester gas to produce electricity for plant use as well as heating the digesters can reduce power costs and increase the reliability of the plant.

Objective: The objective of this project would be to develop a cost-effective, small scale, commercial digester gas cleanup demonstration system that can reduce contaminants so a SCR or oxidation catalyst performance is similar to that of natural gas fueled equipment. An important element of the project would be to show that the gas clean up system would be cost-effective and that combined power cleanup and power generating unit would produce electricity at competitive prices.

Recommended Funding: \$500,000

Background:

It is well known that a SCR and oxidation catalysts are quickly fouled by digester gas fired equipment. Treatment systems such as carbon adsorption and gas chilling will remove most of the harmful gas contaminants. There is limited information however on catalyst life with the treated gas.

Research Approach:

Rather than disrupt an operating unit, the program should involve a wastewater treatment plant with sufficient excess digester gas to fuel a power generating unit that can be connected to displace normal plant electrical usage. Ideally, the engine generator with catalyst would be available and only the gas cleanup train would be required for the demonstration. The unit would be operated continuously with regular measurements of the gas processing performance and air emissions.

15. Energy Optimization of Thermophilic Anaerobic Digestion for Class A Biosolids Production

Description of Issue: A few agencies throughout the US have converted their digesters to operate at thermophilic temperatures for the production of Class A (pathogen-free) biosolids. In addition, local regulations in Southern California require the fecal coliform densities to be non-detect. The temperature clearly is one of the most important parameters in thermophilic processes. An increase of the digester temperature will cause: i) a higher energy demand; ii) a higher rate of disinfection; iii) improved solids destruction and methane production; iv) higher odor emission rates; v) increased maintenance requirements for digesters and ancillary equipment. Federal and local regulations (such as CFR 40 Part 503 Biosolids Rule [USEPA 1993] and SC-AQMD regulations for odor emissions), practical considerations and process economics limit the temperature for operation of thermophilic digesters in the range of in general 120 – 150°F, but usually 120 – 135°F. However, criteria for the optimum digester temperature within this range have not yet been established. Optimization of the digester temperature has potentially a great impact on the energy demand and cost of operation of wastewater treatment plants because of the large volume of waste sludge that needs to be heated.

Benefits for Wastewater Treatment Plants: Successful optimization of the digester temperature will benefit plants in the following ways: 1) energy cost savings by avoiding unnecessarily high temperatures; 2) optimization of total solids destruction and methane production; 3) increased public acceptance by minimizing odor emissions; 4) optimization of disinfection.

Objective: This project would determine the lowest temperature for operation of thermophilic digesters in order to minimize energy use, optimize total solids destruction and methane production, reduce odor emissions, and get the required Class A disinfection.

Recommended funding: \$500,000

Background:

Not much data are available on the energy requirements of thermophilic digestion and the effect of temperature on overall performance. Experiments by agencies (e.g., City of Los Angeles) have indicated that the Class A pathogen density requirements can be met at digester temperatures below that required by the time-temperature requirement of Alternative 1 for batch digestion (EPA Part 503 Biosolids Rule). Hence, potential energy savings are very significant, in particular for plants that process large volumes of sewage sludge. In the case of a plant that heats up 3.5 million gal/day of sludge, the average energy required to raise and hold the digester's temperature one degree Fahrenheit is 17.3 millions BTU_{steam}/day. The projected cost savings of reducing the digester temperature by only one degree Fahrenheit is \$46,000 per year. A larger temperature reduction (5 to 10°F) is likely to be recommended depending on the results of this research proposal.

Research Approach:

Phase I of the proposal concerns laboratory assays with sewage sludge. The temperature would be varied between 120 and 150°F to define a preliminary optimal temperature range regarding solids destruction, methane production, production of odorous compounds and disinfection. The temperature range selected on the basis of Phase I results would be further tested in Phase II pilot scale experiments. These experiments would simulate full-scale digester operation and provide an initial evaluation of overall digester performance in relation to temperature. Phase III research would be performed with full-scale digesters and are meant to verify process design criteria under actual conditions of thermophilic digestion at the plant. Phase III would also allow for the evaluation of the process economics and energy demand of thermophilic digestion. It is expected that Phase I and Phase II research would be six months each, while Phase III may take up to one year.

16. Gas Enhancement During Anaerobic Process of Sewage Sludge by Co-digestion of Organic Solid Wastes

Description of Issue: Anaerobic digestion of sewage sludge is used to disinfect and stabilize sewage sludge. Recovery of methane produced during digestion may reduce the total energy demand of wastewater treatment plants and thus provide a means to lower the plant's operational costs. One alternative to enhance methane production is by simultaneously digesting wastewater sludge with organic-rich wastes (co-digestion).

Benefits for Water and Wastewater Community: Enhancement of methane production by co-digestion would generate considerable savings in the energy consumption of the wastewater treatment plants. For instance, for a plant that

produces 7.1 million scf/day of gas, a 15% increase in gas production, would be equivalent to 62,858 kwh/d. At the current energy prices this may represent a saving of 1 million dollars per year. A second benefit of co-digestion is the integration of the collection, treatment and/or disposal of several municipal and industrial organic wastes. This will provide additional cost and energy savings, e.g., by sharing equipment and better use of the available capacities.

Objective: This project would evaluate the feasibility of co-digesting sewage sludge with other organic wastes in order to enhance biogas production.

Recommended Funding: \$550,000

Background:

Recent reports on co-digestion of sewage sludge at municipal wastewater treatment plants have demonstrated increases in gas production by co-digestion with organic-rich wastes. An increase in gas production between 10 to 20% was reported by co-digesting sewage sludge with fat, oil, and grease (FOG) collected at restaurant interceptors in the City of Oxnard, California. The addition of kitchen and food waste to primary sewage sludge, increased the gas production by 27% in the City of Frutigen, Switzerland. Co-digestion of slaughter wastes with sewage sludge increased the gas production by approximately 60% in the City of Hannover, Germany.

Research Approach:

1. Phase I, laboratory batch assays: Test co-digestion properties and the methane production potential of organic waste available in areas near to the wastewater treatment plant and of potential interest to be used for co-digestion with sewage sludge. Examples are FOG, the organic fraction of municipal solid waste (OFMSW), and other organic wastes.
2. Phase II, laboratory bench-scale reactors: Optimize operational parameters for co-digesting FOG, OFMSW and other organic wastes with sewage sludge. Bench-scale digester experiments will be conducted in order to optimize parameters such as hydraulic retention time, organic loading rate, and waste mixture composition as pertaining to optimizing the methane production.
3. Experimental criteria to be developed during Phase II would facilitate the implementation of pilot-scale studies (Phase III) that will support full-scale tests (Phase IV). These phases of the study would allow the evaluation of the energy and economic benefits of co-digestion of wastewater sludge with other organic wastes.

The study would last for 2 years. Phase I and II would be conducted during the first year. Phase III and Phase IV would be conducted during the second year.

17. Estimation of Embedded Energy in Water

Description of Issue: Many water and wastewater utilities are unaware of the energy associated with their operations. In addition, the energy relationship between water consumption and energy used to treat the resulting wastewater stream are frequently not recognized. By characterizing the water/energy relationship, water and wastewater utilities are likely to more readily motivate policy makers to make infrastructure investments or undertake public policies that reduce demand.

Benefits for Water and Wastewater Community: As the linkages between water consumption and energy use are explored, it would be valuable to estimate typical energy use associated with the consumption of a unit of treated water. This information could prove valuable in public awareness campaigns promoting water conservation and energy efficiency.

Objective: This project would develop a national matrix that shows the relationship between water consumption and energy associated with water and wastewater treatment. These estimates should look at various system capacities, water sources, and regional issues, and develop estimates of the range of variation that would occur. If feasible, a database should be developed from existing data of the actual water and wastewater energy use of major utilities.

Recommended Funding: \$ 200,000.

Background:

The energy efficiency community has not generally been aware of the energy required to treat and transport water and wastewater. Energy savings from water conservation measures are therefore not fairly credited. For example, the national laboratory that performed the energy impact assessment of horizontal-axis washing machines only consider the reduced hot water heating and reduced dryer operation when assessing the energy savings. No value for avoided energy in water treatment or reduced wastewater flows was considered. Having accepted factors for estimating energy effects of water and wastewater treatment would allow more accurate savings estimates.

In addition, water conservation efforts would more easily be able to claim the energy savings co-benefits from their efforts. These savings could be particularly important to municipalities that are currently committing to greenhouse gas reduction targets as a result of national voluntary initiatives.

Significant variations exist between different regions and between different utilities in regions as a result of the source of their water, system configuration, and other requirements. Many utilities have internal estimates of their energy intensity, but this information is locationally specific and not readily available.

National estimates from studies conducted by the Electric Power Research Institute (EPRI) do not adequately capture the variations among the system.

Research Approach:

This is principally an analytical exercise taking available energy use data and developing per gallon estimates of the embedded energy resulting from treatment and pumping for water and wastewater flows. Attempts should be made to develop a matrix of estimates based on general plant characteristics. Data from surveys conducted by major associations (e.g., AWWA and WEF) should be used where possible to develop these high-level energy intensity measures.

18. Development of Anaerobic Treatment Technologies for Municipal Wastewater Treatment

Description of Issue: Wastewater treatment is presently achieved using primarily aerobic processes such as air activated sludge. The aerobic processes have high power demands. An option used presently for treatment of high strength industrial waste is to use an anaerobic process, which does not require aeration air and has the potential for methane generation and energy recovery. Coupling anaerobic processes with membrane filtration can further reduce the foot print and generate recyclable water.

Benefits for Water and Wastewater Community: The benefits of the process include: 1) development of an advanced wastewater treatment technology, 2) substantial reduction in energy demand for wastewater stabilization, 3) improvement of potential for methane generation and energy recovery, 4) reduction in equipment footprint, and 5) elimination of capital and maintenance costs associated with blowers and air diffusers.

Objective: This project would develop and pilot an anaerobic treatment system, coupled with membrane filtration, for wastewater treatment; establish operating parameters and sizing criteria; establish energy saving and power generation potential; and evaluate overall energy and cost savings associated with the process.

Recommended Funding: The total project cost is estimated at \$1,000,000 for the technology development, pilot system design and construction, field installation, testing, and analysis of the results. The funding level can be reduced by reducing the pilot system size and/or operating duration.

Background:

Anaerobic processes are frequently used by industrial discharges for pre-treatment of high strength waste streams. The anaerobic processes offer the benefit of lower power demand, potential for energy recovery, and smaller footprint. While the typical reactors used are up-flow design, research indicates

that other configuration such as baffled reactor or complete mixed or plug flow configurations are also feasible. The typical wastewater, however, has lower strength than industrial wastewater and typically is subject to more stringent treatment standards. As a result, research is needed to establish the reactor configuration for wastewater treatment.

Membranes are currently used in aerobic bioreactors for wastewater treatment. The potential of combining the anaerobic reactor with microfiltration or ultrafiltration membranes in an integrated anaerobic membrane bioreactor to produce recycled quality water is a new application and requires further development.

Research Approach:

The project scope would consist of the two phases as follows:

Phase 1

In this phase, the potential anaerobic reactor configurations would be evaluated and ranked. The potential configurations could include, but not limited to, up-flow reactor, anaerobic baffled reactor, anaerobic pond, complete mixed or plug flow reactors. The screening would be based on potential for energy reduction and methane recovery, overall construction and O&M costs, ease of coupling with membrane filtration, as well as non-monetary factors. Based on this ranking, the reactor configuration would be selected.

Phase 2

In this phase the pilot treatment system consisting of anaerobic reactor and membrane filtration would be constructed for field testing at the participating wastewater treatment facilities. The activities for this phase would include:

1. Conduct bench scale testing to establish operating parameters
2. Design and construct pilot scale system
3. Conduct pilot testing at the selected wastewater treatment plant site
4. Based on operating results establish the optimum operating parameters and energy saving/generation potential
5. Conduct cost-benefit analysis for the system.

19. Development of Customized Pretreatment and Diversion Programs

Description of Issue: Many wastewater treatment facilities are overtaxed by upstream users. Enhanced pretreatment and diversion by users would alleviate significant burdens on the wastewater facilities.

Benefits for Water and Wastewater Community: Enhanced pretreatment and diversion could reduce the loadings conveyed to municipal wastewater treatment facilities. Pretreatment could include water conservation and diversion, solids diversion and BOD pretreatment and diversion. Additionally, BOD pretreatment could be utilized by the industrial user to generate bio-gas for use at their facility, and pretreatment could lower all parties' costs.

Objective: The objective of this project would be to evaluate the customization of pretreatment programs for cost-effectiveness and energy efficiencies.

Recommended Funding: \$200,000

Background:

Many substances that are now disposed of through the sewer system could be recycled or economically disposed of in other manners. Customized pretreatment could include prohibiting garbage disposals, gray water recycling, diversion of stormwater, or pretreatment of high strength BOD and/or solid wastes streams.

Research Approach:

This study would identify the potential benefits of residential and commercial pretreatment and diversion programs. It would also identify realistic approaches to implement such programs.

20. UV Disinfection: Develop Next-Generation Energy Efficient UV Disinfection Systems for Water and Wastewater Treatment

Description of Issue: UV disinfection provides cost effective inactivation of waterborne pathogens including *Cryptosporidium* and *Giardia*, all without the formation of disinfection by-products but at a high energy cost. Optimization of existing systems is a current practice so research needs to drive new equipment development with consideration to system operations.

Benefits for Water and Wastewater Community: UV disinfection does not involve the transport and use of hazardous chemicals, occupies a small footprint, and is simple to operate and reduces operating costs. The next generation of UV equipment will provide greater energy efficiency.

Objective: This project would identify the opportunities for the development or application of new UV equipment technologies that are effective and energy efficient, and explore other industry uses of UV for application to water and wastewater.

Recommended Funding: \$75,000 for a paper study.

Past and Ongoing Research: Numerous optimization studies are available for current technology application and use.

Background: N/A

Research Approach:

This project would involve a paper study to look at current technologies and equipment, obtain industry input, and explore non-water/wastewater utility

applications of UV technology for possible use or modification for water/wastewater use.

21. Explore Options for Decentralized and Small-Scale Wastewater Treatment Systems that are Energy Efficient

Description of Issue: A large percentage of energy used for wastewater management is used to transport wastewater to centralized wastewater treatment plants. Also, centralized treatment of large volumes of wastewater can be energy intensive. Collection and treatment of wastewater at a conventional, centralized wastewater treatment plant may not be the best wastewater management alternative for all situations. Decentralized wastewater treatment may be more cost effective and result in less environmental impact for geographically dispersed development or densely concentrated populations where on-site wastewater treatment and disposal systems are used. Compilation of the construction, operation and maintenance costs associated with decentralized systems using various collection and treatment technologies, would be useful to evaluate wastewater management alternatives. A separate evaluation of the energy use and costs would provide useful information for energy optimization.

Benefits for Water and Wastewater Community: If the energy use and costs of constructing, operating and maintaining decentralized wastewater collection and treatment systems were available, decision makers could use the energy information as part of the equation to make wastewater management decisions.

Objective: This project would develop a model to predict energy use and cost of capital and operation and maintenance of a variety of decentralized wastewater collection and treatment systems. Compare to energy use and cost of capital and operation and maintenance of the expansion of centralized wastewater collection and treatment facilities.

Recommended Funding: \$250,000 over two years.

Background:

As the use of on-site wastewater treatment and disposal systems (e.g., septic tanks and leach fields) becomes problematic due to increasing population densities and resulting groundwater contamination, alternative treatment strategies are needed. The cost of expanding existing centralized treatment system is often prohibitive due to cost of collection systems and pumping stations, and availability of new centralized treatment sites. The use of alternative decentralized technologies may be attractive because they are less costly and use less energy than technologies normally utilized in larger-scale,

centralized systems. In addition, these decentralized systems may also offer an opportunity for pretreatment and primary treatment of wastewater to address capacity constraints at existing facilities experiencing capacity growth.

Research Approach:

Model inflow characteristics would be developed for prototypical applications. Existing small-scale treatment technologies would be reviewed, and different system configurations using these technologies would be assembled to meet the model needs. Examples of on-site, decentralized wastewater treatment include recirculating sand filters and mound systems, or aerobic treatment tanks and leach fields. Also, STEP/STEG (septic tank effluent pumping/gravity) collection systems can bypass leach fields and prevent groundwater contamination by conveying primary septic tank effluent to a small, decentralized advanced wastewater treatment facility such as Advanced Integrated Wastewater Pond System (AIWPS). Operational regimes for these model systems will be explored and used to develop guidelines for the operation and maintenance of these facilities. Estimates of energy use and cost of capital and operation and maintenance for the model systems will be developed and compared to costs and energy use to treat the wastewater flow through expansion of central wastewater treatment facilities.

22. Enhancing Biological Oxygen Demand and Suspended Solids Removal Prior to the Activated Sludge Process in Wastewater Treatment Plants.

Description of Issue: Energy associated with the secondary processes in wastewater treatment plants (WWTPs) is huge. Any method to optimize energy consumption here is valuable. Primary clarifiers are the standard of the industry for removal of BOD and SS prior to the secondary process. Several methods of optimizing performance of primaries, or replacement of primaries with other more effective processes should be investigated.

Benefits for Water and Wastewater Community: This project will compile information that would help wastewater utilities reduce energy consumption and cost for the activated sludge process, reduce sludge production, improve odor control (if ferric is used for CEPT), improve dewatering, and enhance digester gas production (and accompanying increase in energy production in cogeneration facilities).

Objective: This project would investigate a variety of alternatives to enhance the removal of BOD and SS prior to the secondary process. These could include chemically enhanced primary treatment (CEPT), primary effluent filtration, ballasted flocculation (e.g. Actiflo), ABR, and other unit operations.

Recommended Funding: \$200k to \$250k for the initial study, \$100k stipend for each field test conducted (maximum of 3), \$125k for final analysis of data and preparation of report.

Past and Ongoing Related Research: Research of many of the potential alternatives has been conducted. Some of the alternatives have been implemented full scale.

Background:

CEPT has been used for years at facilities that desire to reduce energy use, remove phosphorus, and enhance removal of BOD and suspended solids. In the past 10 years, many other unit operations have emerged that can enhance the removal of these constituents from raw sewage. Unfortunately, oil and grease and high costs have complicated the implementation of these unit operations. This investigation will consolidate the data, research, and operational aspects of the alternatives in one place so that readers can determine the economic and aesthetic considerations for alternatives to conventional primary treatment.

Research Approach:

A literature review would be conducted to evaluate alternatives and identify the two to four alternatives to be evaluated in pilot scale testing. The literature review would:

- Determine available technologies
- Review, consolidate and report available published material
- Create “long list” of potential alternatives
- Perform analysis of alternatives-cost, savings, other benefits, challenges, disadvantages, safety, etc.
- Visit plants where alternatives are implemented or being piloted or researched
- Rank and describe the top 2-4 alternatives to be researched or investigated further
- Describe further work and research to be done.
- Prepare draft and final reports.

Pilot scale research would then be conducted on the top two to four alternatives. A summary of the literature review and analyses of the data from the pilot studies would be prepared in a summary report.

23. Waste Activated Sludge Conditioning Prior to Anaerobic Digestion to Enhance Treatability and Dewatering.

Description of Issue: Waste activated sludge (WAS) is a problem at WWTPs. Is difficult to dewater, does not degrade easily in the digestion process, and produces large volumes of residuals for disposal. Proper conditioning of this sludge prior to digestion could reduce the problems and enhance biogas production in digesters.

Benefits for Water and Wastewater Community: Lower sludge production, better digester gas production, more potential for energy production in

cogeneration, lower costs and energy associated with biosolids dewatering and disposal.

Objective: This project would investigate the breakdown of (find the holy grail for breaking) the cell wall of WAS, thus allowing the contents of the cells to be available for degradation in the anaerobic digestion process.

Recommended Funding: Initial study to identify and rank alternatives: \$200 to 250K, Research for top 2-3 alternatives: 100k each, and follow-up report- \$125 to 150k.

Past and ongoing research: Considerable research has been done and results need to be summarized.

Background:

Finding an economical solution for breaking the cell walls of WAS has been a stumbling block in the profession for years. Many techniques have been tried including, mechanical abrasion, the “crapper zapper” (electric arc), chemical conditioning, etc. All have been ineffective due to cost considerations, high maintenance or marginal performance. New technologies like ultrasound and steam explosion show promise but are unproven.

Research Approach:

The project tasks would include:

1. Determine available technologies
2. Review, consolidate and report available published material
3. Create “long list” of potential alternatives
4. Perform analysis of alternatives including: cost, savings, other benefits, challenges, disadvantages, safety, etc.
5. Visit plants where alternatives are implemented or being piloted or researched
6. Rank and describe the top two to four alternatives to be researched or investigated further
7. Describe further work and research to be done
8. Prepare draft and final reports.

Conduct pilot research on the top two to four alternatives. Research may not be needed on alternatives that are currently used. Develop a summary report.

24. Barriers to Using Fine Pore Aeration Systems at Small Treatment Plants.

Description of Issue: Aeration is the most energy intensive aspect of secondary treatment. Typically 40 to 60% of the power consumption at a treatment plant is consumed by aeration. In the 1980's, the US EPA and ASCE pioneered the development and implementation of fine pore aeration systems, which can save 50% of the power expended on aeration. Most large plants and some smaller plants have embraced this technology. In spite of its obvious benefits, many smaller and medium size plants do not use the technology. Some known reasons include maintenance cost, lack of capital and pessimism about the technology.

Benefits for Water and Wastewater Community: This project could provide information to help small wastewater treatment plants implement fine pore aeration systems that would result in energy savings for small treatment plants.

Objective: This project would determine the barriers (economic, technical or regulatory) preventing small wastewater treatment plants from utilizing high efficiency fine pore aeration systems.

Recommended Funding: \$50,000-\$150,000 for a paper study

Background:

Many small plants currently use small fine pore systems. All economic analysis of the energy savings of implementing the technology shows that it has positive payback after only a few (3 to 5) years. Determining why some small plants are successful and others are not in implementing the technology will allow many additional plants to conserve energy. There will also be benefits to reducing peak power consumption, since aeration systems usually operate at maximum rate in the summer and late afternoon hours.

Research Approach:

The project tasks would include:

1. Survey small plants to determine what barriers exist for implementing fine pore aeration technology.
2. Select a subset of plants for interviews and further analysis.
3. After barriers are identified, determine what solutions exist.
4. Assemble a team of experts to review and advise as the project is conducted.

25. Recovery and Use of Digester Gas at Small Wastewater Treatment Plants.

Description of Issue: Digester gas (65% methane, 35% carbon dioxide) is routinely used at large treatment plants for power generation. Small plants often use digester gas for heating only, flaring the remainder. The research issue is to determine what technical or institutional barriers prevent small plants from fully recovering the energy from digester gas.

Benefits for Water and Wastewater Community: This project could provide information to help small wastewater treatment plants implement digester gas recovery systems for power generation, resulting in energy savings for small treatment plants.

Objective: This project would determine the barriers (economic, technical or regulatory) that prevent small wastewater treatment plants from recovering more energy from digester gas.

Recommended Funding: \$50,000-\$150,000 for a paper study

Background:

Some small plants currently use small co-generation systems or other recovery technologies, while the vast majority do not. Determining why some small plants have successfully implemented co-generation systems and others have not, may allow many additional plants to recover energy.

Research Approach:

The project tasks would include:

1. Survey small and large plants to determine what motivates them to recover or not recover energy from digester gas. Also research published and gray literature to see what surveys have been done before.
2. Select a subset of plants for interviews and further analysis.
3. After barriers are identified, determine what solutions exist.
4. Assemble a team of experts to review and advise as the project is conducted.

26a. Guidance Manual: Protecting Treated Water Quality While Reducing Energy Costs

Description of Issue: As energy and time-of-use costs increase, water utilities face the challenge of protecting treated water quality while reducing energy costs. This project would identify treated water quality risks associated with certain energy management practices.

Benefits for Water and Wastewater Community: This project would identify potential water quality risks associated with managing electrical consumption. The guidance manual would provide utilities with an improved understanding of energy management practices that may negatively affect treated water quality or treatment efficacy.

Objective: This project would identify energy management or energy conservation approaches that may impact the quality of treated water effluent as it leaves the treatment plant or effect the efficacy of drinking water treatment, and identify solutions to mitigate the risks.

Recommended Funding: \$250,000

Background:

The primary goal of a drinking water utility is to produce safe, aesthetically pleasing, water in an economically and environmentally responsible manner. As energy costs increase, normal water treatment operating practices may be questioned or adjusted to conserve energy.

Energy conservation approaches that may compromise water quality or treatment efficacy include (1) reducing energy-intensive disinfectant dosages; (2) eliminating pre- or intermediate- disinfectant/oxidant dosages; (3) extending filter run lengths; (4) staging or delaying backwashing to off-peak energy rates; (5) adjusting treatment plant flow to off-peak energy rates; and (6) decreasing mixing energy.

Drinking water treatment facilities are also increasing the amount of electrical load that may be price sensitive or interruptible. These facilities either rely on system storage or standby/emergency power to continue potable water deliveries.

Research Approach:

The following tasks would be performed for this project:

1. Identify energy management practices that may affect effluent water quality or treatment efficacy.
2. Conduct a sensitivity analysis of the potential water quality impacts to the identified energy management practices.

3. Provide clear guidance for utilities to effectively manage energy and avoid risk to potable water quality.

26b. Guidance Manual: Protecting Distribution System Water Quality While Reducing Energy Costs

Description of Issue: As energy and time-of-use costs increase, water utilities face the challenge of protecting post-treated water quality within the distribution system while reducing energy costs. Energy management practices may have the capability to negatively impact the quality of water within utility water distribution systems. This project addresses water quality risks in the distribution system associated with certain energy management practices.

Benefits for Water and Wastewater Community: This project would identify potential water quality risks in the distribution system associated with managing energy consumption. The guidance manual would provide utilities with an improved understanding of energy management practices that may negatively affect post-treated potable water quality within the distribution system.

Objective: This project would identify energy management or energy conservation approaches that could affect the quality of potable water within the distribution system and identify solutions to mitigate the risks and prevent the identified negative impacts.

Recommended Funding: \$250,000

Background:

The primary goal of a drinking water utility is to produce safe, aesthetically pleasing, water in an economically and environmentally responsible manner. As energy costs increase or energy tariffs change, normal water distribution operating practices need to be questioned and/or adjusted to reduce energy costs.

Energy cost reduction approaches that could compromise water quality include longer reservoir retention times which would affect nitrification issues, disinfection byproducts issues, water aesthetics and consistency.

Research Approach: The following tasks will be performed for this project:

1. Identify energy management practices that may affect post-treated potable water quality.
2. Conduct a sensitivity analysis of the potential water quality impacts to the identified energy management practices.
3. Provide clear guidance for utilities to effectively manage energy and avoid risk to potable water quality.

27. Energy Consumption for Potable Water Conveyance and Treatment in Southern California Region

Description of Issue: Alternative water sources in the Southern California region require vastly different amounts of energy to deliver potable supplies to the consumer. Advances in alternative technologies such as reverse osmosis and ultraviolet light now make new supplies such as brackish groundwater, agricultural drainage water, reclaimed wastewater and seawater more feasible. The energy cost to produce potable water from these supplies varies substantially.

Benefits for Water and Wastewater Community: This project would clearly determine energy consumption for potable water conveyance and treatment in Southern California. Data from this project would guide utilities and State energy policymakers towards sound management decisions for new water supplies.

Objective: This project would identify the range of energy use and costs of conveyance and treatment in Southern California. It would compare the range of energy use and costs for seawater desalination to the energy used to convey and treat imported and other local supplies.

Recommended Funding: \$150,000

Background:

Importing water into the Southern California region requires a net 3,200 kWh/ac-ft (for California State Project Water) to a net 2,000 kWh/ac-ft (for Colorado River water). New, local supplies require much less energy to convey water to the consumer, but the energy for treatment increases dramatically. [Figure A.1](#) shows this effect. Seawater desalination, in particular, requires a large—though still widely variable—amount of energy for treatment. A brief review of current and planned seawater desalination plants shows that the energy of treatment ranges from 3,100 kWh/ac-ft to 4,900 kWh/ac-ft, with an average of 4,200 kWh/ac-ft. It is unknown whether the energy consumption of seawater desalination can realistically be lower than that of importing supplies from Northern California.

Research Approach:

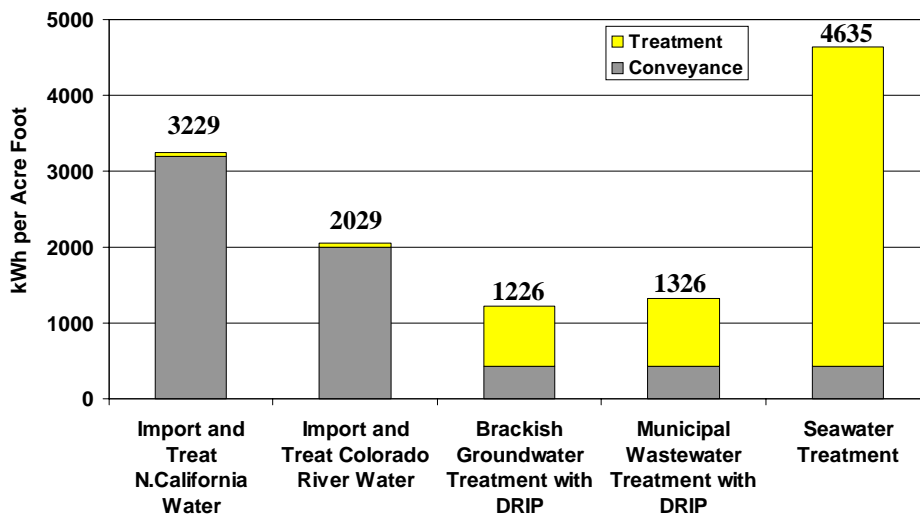
Researchers would work with regional and State agencies to determine the energy required for conveyance and treatment of water supplies. Most of the work would focus on determining realistic energy requirements for seawater desalination.

Suggested tasks include:

1. Determine treatment and conveyance energy and costs (on a per acre-ft basis) for the major current sources of water in Southern California. These waters include: California State Project water (East and West

- Branch), Colorado River water, Eastern Sierra runoff (Los Angeles Aqueduct supplies), local groundwater, local runoff, brackish groundwater, and reclaimed wastewater.
2. Investigate the range of seawater desalination energy use and cost. Survey existing seawater desalination energy use (membrane treatment only) and the cost of securing that energy.
 3. Analyze the effects of price-sensitive or interruptible energy supplies to convey and treat local, imported, and desalted supplies.
 4. Determine the energy competitiveness of (a) seawater versus imported supplies and (b) imported versus reclaimed supplies.

Figure A.1: Energy Consumption for Potable Water



28. Primary Effluent Microfiltration – Secondary Treatment Alternative

Description of Issue: Activated sludge secondary treatment is very expensive and energy intensive to operate. AS plants produce sludge that is difficult and costly to dewater. Micro or ultrafiltration is a technology that could partially replace conventional activated sludge secondary treatment. Membrane-filtration technology has been demonstrated for clean water applications, but not dirty water applications. Studies and tests of membrane-filtration for use on primary effluent need to be conducted in order to determine removal rates, capital, and life-cycle costs, to determine if this technology could cost-effectively replace activated sludge, and to determine the benefits of this proposal.

Benefits for Water and Wastewater Community: This project will compile information that would help wastewater utilities reduce energy consumption and operating cost for the activated sludge process, reduce sludge production, improve dewatering, and improve water quality.

Objective: The objective of this study would be to demonstrate the use of membrane-filters (micro or ultrafiltration) in lieu of, or in addition to, secondary wastewater treatment. Alternative limits for biochemical oxygen demand (BOD) would also be studied for ocean discharges or for discharges to major water sources (modification to Clean Water Act, CWA)

Recommended Funding: \$2,000,000 (\$200,000 for case study on receiving water bodies and \$1,800,000 for research study with pilot facilities)

Potential Controversial Issues: Clean Water Act (CWA) requirements don't currently consider the capacity of receiving waters to accept BOD and TSS. Since BOD is not completely removed by microfilters, BOD requirement may need to be amended to accommodate this use of microfilters. A study of large receiving bodies of water and the capacity to handle BOD must also be conducted as part of this work.

Past/Ongoing Related Research: Orange County Sanitation District, California has started a small pilot plant to begin gathering information on primary effluent filtration. Orange County Water District, California research results show effluent suspended solids less than 5 mg/L are achievable with nearly 100% removal of particulate BOD.

Background:

Conventional activated sludge treatment of wastewater is very energy intensive and incurs high operational costs. In addition, the AS secondary treatment solids are difficult to dewater and handle. Membrane-filtration of primary effluent, in lieu of secondary treatment, may be a viable alternative.

Research Approach:

Conduct a paper or case study on the impacts of BOD on large receiving water bodies (e.g., Pacific Ocean, Atlantic Ocean, major lakes and rivers) for possibilities of amending the CWA requirements for BOD.

Operate a one or two MGD microfiltration pilot plant for primary effluent treatment in order to study:

- bacteria reduction (for disinfection purposes)
- sludge (solids) reduction over conventional activated sludge treatment
- comparison of energy consumption, footprint, O&M cost, and capital costs.

29. Comparison of Electrodialysis Reversal (EDR) Costs and Performance to Low and High Pressure Reverse Osmosis (RO) Systems for Desalination

Description of Issue: Reverse osmosis (RO) systems have high energy consumption. New D/E systems tend to have high operation and maintenance costs.

Benefits for Water and Wastewater Community: Understanding the benefits of D/E systems cost-effectiveness would help to determine if D/E is a viable alternative to RO.

Objective: The objective of this project would be to conduct a cost benefit analysis of D/E and RO systems to help drinking water utilities determine if D/E systems are a viable alternative to RO systems.

Recommended Funding: \$100,000

Background: N/A

Research Approach:

A detailed study of costs (initial, energy, operations and maintenance) should be commissioned. It should evaluate costs of existing installations.

30. Peracetic Acid Pilot Study for Effluent Disinfection

Description of Issue: Most water and wastewater plants use chlorine, bleach, and ultraviolet radiation, among other traditional disinfection methods. Most chemicals have toxic or harmful byproducts and UV disinfection is a high energy user. Peracetic acid has been demonstrated as a strong disinfectant but is primarily used in other industries, like the medical profession. Peracetic acid is completely biodegradable and does not typically require neutralizing agents like dechlorination agents. In addition, peracetic acid systems do not consume large amounts of energy. Peracetic acid is currently cost prohibitive to use because the chemical is not mass produced. In addition, only a few treatment plants in Europe and Canada have used this process on a full scale basis.

Benefits for Water and Wastewater Community: Peracetic acid could provide an energy friendly and non-toxic alternative to UV disinfection and chlorine-type disinfection methods.

Objective: The objective of this study would be to demonstrate and evaluate the use of peracetic acid, to evaluate plant effluent toxicity, and the existence of harmful byproducts. In addition, the study would compare the use of peracetic acid to UV irradiation for disinfection purposes, as well as determine the break even unit cost for these technologies.

Recommended Funding: \$1,000,000

Past/Ongoing Related Research: Europe and Canada

Background:

See description, above.

Research Approach:

Conduct 1 MGD pilot and paper study. Demonstrate effectiveness and potential to replace conventional methods of disinfecting plant effluent.

31. Recuperative Thickening of Anaerobic Digestion for Enhanced Gas Production

Description of Issue: Gas production and sludge destruction may be enhanced by thickening and returning digested sludge to the anaerobic digester for further treatment. This “activated” anaerobic sludge treatment approach, which requires a thickening process on the back end of the digester, can increase the solids retention time by two to three fold without increasing the hydraulic retention time. The thickening process may also provide an elutriation of the digester contents, potentially reducing inhibitory effects. The savings from increased gas production and the lower costs associated with having less sludge to dewater and haul, must be weighed against the additional costs associated with the recuperative process, e.g., recuperative polymer use, increased digester mixing.

Benefits for Water and Wastewater Community: Benefits include increased digester gas production due to increased sludge destruction, less sludge to dewater, and less biosolids to haul and dispose/reuse. Additional benefits may include lower biosolids odors, better sludge dewaterability, higher digester gas quality, lower digestion and dewatering capacity, and a reduction in raw sludge thickening costs. The thickening return sludge may provide a more economical approach to reach Class A Biosolids through the time-temperature requirement.

Objective: The objective of this project would be to demonstrate the economic and energy benefits and costs of recuperative thickening for anaerobic digestion, and to evaluate the various approaches to recuperative thickening.

Recommended Funding: \$300,000

Past/Ongoing Related Research: Various pilot-scale and full-scale recuperative thickening tests have been performed. Some of the results are well distributed, while the results of others are less known. King Co., WA. tested the anoxic gas flotation (AGF) recuperative thickening process at pilot scale in the early 90's. Volatile solids destruction increased from about 60% to about 68% at a 20-day solids retention time. Orange Co. Sanitation District is currently performing a test of the AGF process at a larger pilot scale. The Spokane, WA.

Wastewater Utility operated a centrifuge for recuperative thickening in the mid-90's; they are no longer running this process. The Phoenix WWTP was also planning to use a centrifuge for recuperative thickening. A smaller wastewater plant in the Seattle Metropolitan area (Southwest Suburban's Salmon Creek Plant) is currently operating an AGF recuperative process.

Background:

Recuperative thickening or "activated" anaerobic sludge is not a new concept. In fact, recuperative thickening has been tried by WWTP with insufficient digester capacity, and/or inadequate raw sludge thickening. The recent interest in recuperative thickening is more directed at expanding the capacity of digesters, i.e., smaller digesters, rather than increased gas production. Test results show that gas production can be increased significantly for a given hydraulic retention time.

Research Approach:

The research would consist of the following tasks:

1. Conduct literature review
2. Prepare project report and plan
3. Conduct large-scale or full-scale pilot
4. Publish final report and findings.

32. Energy-Efficient, Carbon-Efficient Advanced Wastewater Treatment for Natural Systems

Description of Issue(s): There are approximately 9,000 municipal waste stabilization ponds in the U.S. and there are approximately 900 in California. Virtually, all of these so-called natural systems are in need of retrofitting in order to improve their effluent quality and environmental compliance, to reclaim wastewater, and to implement water recycling. These alternative advanced systems optimize anaerobic digestion, photosynthetic oxygenation, high rate oxidation, and biological nutrient removal, and they are significantly more energy efficient than conventional tertiary wastewater treatment facilities.

Benefits for Water and Wastewater Community: Water recycling may offset the use of groundwater, surface water, and/or potable water supplies. Therefore, advanced treatment and reclamation will extend available water resources. Typically, advanced treatment (tertiary stage treatment that meets Title 22 unrestricted reuse quality standards) doubles the operational cost and energy requirements of conventional, or natural, secondary wastewater treatment plants. But by retrofitting existing natural systems, such as oxidation ponds or waste stabilization pond systems, using advanced technology to achieve tertiary level treatment and Title 22 reuse requirements, advanced treatment and water recycling can be implemented at half the cost and a fraction of the energy of conventional tertiary treatment. In addition to wastewater reclamation and reuse,

biogas may be recovered from in-pond digesters (preventing its emission to the atmosphere) and used to generate electricity thereby improving the overall energy efficiency of the wastewater treatment process. Finally, nutrients in the form of algal biomass harvested from advanced natural systems can be recovered and recycled as a nutrient-rich fertilizer and soil amendment or, after disinfection, as a protein-rich animal or fish feed.

Objective: The objective of this study would be to demonstrate and quantify the energy-efficiency and additional environmental benefits of advanced natural systems for primary, secondary and tertiary treatment. The project would also demonstrate water reuse, biogas recovery and power generation, and nutrient recovery and recycling.

Recommended Funding: \$500,000 for the demonstration and case study;
\$5,000,000 total project cost

Past and Ongoing Related Research:

J.B. Downing, E. Bracco, F.B. Green, A.Y. Ku, T.J. Lundquist, I.X. Zubieta, W.J. Oswald. (2002) "Low cost wastewater reclamation using the Advanced Integrated Wastewater Pond Systems technology and reverse osmosis" Water Sci. & Tech., Vol. 45, No. 1, pp. 117-125.

F.B. Green, "Avoidance and Mitigation of GhG Emissions and Microalgal Biofixation of CO₂ using the AIWPS® Technology." (2001) Presented at the Workshop on Biofixation of CO₂ and Greenhouse Gas Abatement with Microalgae sponsored by the International Energy Agency, U.S. Department of Energy, and EniTecnologie, 22-23 January 2001, Monterotondo, Italy.

F.B. Green, T.J. Lundquist and W.J. Oswald. (1995). "Energetics of Advanced Integrated Wastewater Pond Systems" Water Sci. & Tech., Vol. 31, No. 12, pp. 9-20.

F.B. Green, L. Bernstone, T.J. Lundquist, J. Muir, R.B. Tresan, and W.J. Oswald. (1995). "Methane Fermentation, Submerged Gas Collection, and the Fate of Carbon in Advanced Integrated Wastewater Pond Systems" Water Sci. & Tech., Vol. 31, No. 12, pp. 55-65.

Background:

Research Approach:

Partner with a California municipality that is currently upgrading an existing wastewater pond facility. Implement design improvements in the primary anaerobic treatment processes as well as the biological secondary treatment processes and add tertiary treatment components to meet Title 22 unrestricted reuse quality. Practice water recycling to extend available potable water resources. Document and account for cost and energy savings as compared

with earlier performance, other natural systems and with conventional tertiary wastewater treatment facilities.

33. Zero Liquid Discharge for In-Land Desalination

Description of Issue: New cost effective, low energy technologies need to be developed to dispose of desalination concentrate. Not only are methods needed to remove the water from the salt, methods are needed to recover the water from the concentrate.

Benefits for the Water and Wastewater Community: Many communities have access to additional sources of water with marginal quality. In order to accommodate growth, new sources of water must be found. Desalination of the marginal quality water sources is cost effective when there is an economical method to dispose of the remaining salts. New methods of disposal should not only dispose of the salt, but should recover the remaining water in the concentrate stream for beneficial uses.

Objective: The objective of this project would be to develop energy efficient, low cost methods of zero liquid discharge for brackish water sources and toxic irrigation return flows.

Recommended Funding: \$500K for two years

Past and Ongoing Related Research: The Department of Interior's Office of Saline Water and the Office of Water Research and Technology sponsored various investigations in the 1960s through the early 1980s. The California Department of Water Resources has also sponsored work. Related work is being investigated by Mike Mickley of Mickley and Associates in Boulder, CO for the U.S. Bureau of Reclamation. The Salton Sea Authority and Reclamation have also done work on evaporation and enhanced evaporation technologies. The cities of Phoenix, AZ and El Paso, TX are actively looking at in-land concentrate disposal methods including zero liquid discharge. There are also various power plants and industries that currently use energy intensive methods.

Potential Controversial Issues: The desalination of irrigation return flows may not be approved for drinking water purposes. The remaining salt will need to be disposed in an acceptable manner, if a commercial use cannot be found. Currently, there are no commercial uses of the salt by-product.

Background:

Disposal of concentrate from inland desalination processes has become the major limiting factor in selecting desalination treatment technologies. The ultimate goal is to have no discharge of concentrate back into the environment. Unfortunately, separating the remaining dissolved salts from solution requires energy. The least expensive solution has been to use solar energy and

evaporation ponds, when land has been cheap and evaporation rates have been high. The alternatives become more expensive and include deep well injection, enhanced evaporation through spray technologies, and energy intensive mechanical evaporation technologies.

Research Approach:

The research would consist of the following tasks:

1. Conduct literature search for past projects/technologies and status of current research projects.
2. Develop test program for lab-scale testing to evaluate two or three innovative, energy efficient and complete removal methods of toxic components.
3. Carry out test program.
4. Develop final report including recommendations for further studies.

34. The Cost and Value of Recycled Water

Description of Issue: The energy cost of conventional wastewater treatment with nitrification is approximately 3000 kWh/MG. Filtration, membrane treatment, temperature reduction, and potentially reverse osmosis could raise this energy consumption to 5000 to 10,000 kWh/MG. The economic and environmental costs of discharging wastewater may become prohibitively expensive. In addition, water supplies are dwindling causing water suppliers to seriously examine the use of reverse osmosis to recycle wastewater. Reverse osmosis consumes approximately 6000 – 8000 kWh/MG and are comparatively expensive to construct. Water imported to southern California from the north requires approximately 5000-6000 kWh/MG. Reclaimed water can be delivered as part of the state's "water supply" for a fraction of the capital and energy cost of desalination (as low as 1000 kWh over the cost of conventional title 22 treated effluent.)

Benefit for Water and Wastewater Community: This supply provides multiple benefits including, introduction of fewer contaminants in watercourses, reduction of energy costs for water supply, provision of a new source of water supply, elimination of brined discharges, and is availability of virtually every community.

Objective: The objective of this study would be to conduct a university-based study to compare the cost of delivering reclaimed water with the cost of desalination and other potential water sources.

Recommended Funding: \$250K / 2 years

Potential Controversial Issues: Reclaimed water can be a tough sell compared to other potable water sources.

Background: N/A

Research Approach: This research project should be conducted in the following phases:

1. Conduct literature search of the historical water value comparisons.
2. Develop the analysis framework.
3. Submit report of analysis framework to Project Advisory Committee.
4. Conduct analysis.
5. Submit final report.

35. Development of Recycled Water Quality Indicators for Reclaimed Waters Used for Ground Water Recharge

Description of Issue: Reclaimed water is a significant resource and is utilized by many agencies in California to recharge the groundwater supplies. The most common recharge method is using either secondary or tertiary (Title 22) treated water in spreading basins. The current requirement for judging the quality of the reclaimed water used for recharge is a limit of 1 mg/l Total Organic Carbon (TOC). Due to detection of pollutants such as NDMA, the regulatory agencies are proposing to reduce this limit to 0.5 mg/l. This new limit necessitates membrane treatment, thus, substantially increasing the reclaimed water cost and availability for groundwater recharge. Additionally, scientific data is not available to justify the use of TOC as an indicator for suitability of reclaimed water for groundwater recharge. Therefore, scientific research is needed to develop proper quality indicators for these applications of the reclaimed water.

Benefits for Water and Wastewater Community: The benefits of this research include: 1) developing a scientifically based quality indicator for protecting public health in recharge application of reclaimed water; 2) maintaining reclaimed water as a viable resource for ground water recharge; and 3) keeping the cost of water reclamation affordable levels..

Objective: The objective of this project would be to develop a scientifically based quality indicator for judging the suitability of reclaimed water for ground water recharge, protect public health, and suggest proper treatment levels needed to meet the proposed quality indicator.

Recommended Funding: The total project cost is estimated at \$1,000,000 for literature research, field sampling and testing, analysis of the results, and development of the quality indicators and proper treatment levels.

Background:

The reclaimed water is typically supplemented by fresh water or storm runoff such that the reclaimed water is 35% of the total recharged volume. The indicator currently used by regulatory agencies to establish the suitability of the reclaimed

water is TOC. A TOC of 1 mg/l or less was deemed to represent adequate reclaimed water quality for groundwater recharge. However, the recent discovery of trace contaminants such as NDMA has triggered the need to revisit the adequacy of 1 mg/l TOC limit. Recently, regulatory agencies proposed a 0.5 mg/l TOC requirement, measured in the recharge mound, in absence of dilution water as the limit for judging the suitability of the reclaimed waters used for groundwater recharge. Complying with this stringent limit would necessitate membrane treatment, thus substantially increasing the reclaimed water cost and will limit the availability of reclaimed water supplies for groundwater recharge.

Research Approach:

The project scope would consist of the following:

1. Conduct literature search on the work previously done to develop reclaimed water quality indicators for ground water recharge.
2. Establish the project advisory and review committee.
3. Based on the literature review, develop a field sampling and testing protocol.
4. Conduct sampling and analysis.
5. Conduct review of the protocol and regular review of the testing results with the advisory and review committee.
6. Modify field sampling and testing protocol based on field results and input by advisory and review committee as the project progresses.
7. Based on sampling results develop the quality indicator(s), appropriate limits, and suitable treatment technologies.

36. Thermodynamic Evaluation of Advanced Water and Wastewater Treatment Technologies

Description of Issue: The operation of advanced water and wastewater plants is inadequately characterized for energy usage. In order to make energy efficiency improvements to advanced treatment process, the first step is to characterize the existing operations.

Benefit for Water and Wastewater Community: The goal of reducing energy usage will be guided by a solid understanding of the unit operation energy consumption processes.

Objective: The objective of this study would be to conduct a university-based study of the energy use, cost, and efficiency of water and wastewater unit operations. It should include a comparison with theoretical efficiencies and an identification of the largest energy usages. The study should conduct the comparison of 12 different plants to include advanced water and wastewater treatment processes including desalination.

Recommended Funding: \$250K / 2 years

Background:

While unit operations is a standard part of the university curriculum for undergraduate students in a variety of engineering disciplines, the energy balance associated with water and wastewater treatment processes has not received adequate attention to analyze the most important energy sources and sinks.

Research Approach:

This research project should be conducted in the following phases:

1. Conduct a literature search of the historical energy analyses of advanced water and wastewater treatment unit operations.
2. Develop the energy analysis framework.
3. Select 12 plants that will be analyzed.
4. Submit report of analysis framework and plant selection for review by Project Advisory Committee.
5. Conduct energy audit.
6. Submit final report.

37. Development of a Guidance Manual to Design/Operate Desalination Facilities for Maximum Energy Efficiency

Description of Issue: Desalination is increasingly becoming a major source of new water supply (e.g. California, Texas, and Florida). This technology is inherently electrical energy intensive. New facilities will put a further large demand on the electrical systems. The intent of this project is to provide guidance to design/operate the facility to optimize the electrical energy utilization. In the United State, the electrical rate structure encourages off-peak power usage (time of use). Designs utilizing these features may substantially reduce operating cost.

Benefits for Water and Wastewater Community: Load shifting (minimum of power at peak hours) which will result in minimize operating cost.

Objectives: Based upon current operating experience and conceptual design, this project would result in a design/operating manual for the water community to guide their future designs/operating plans.

Recommended Funding: Total project cost is \$150,000.

Past and Ongoing Related Research: AwwaRF is developing knowledge on MF and UF facilities for plants over 1 MGD using brackish, groundwater, agricultural, and reuse. COMMISSION is doing similar work water source plus seawater desalination with the additional of capital, operating, and chemicals,

and labor costs. This project would not duplicate these efforts but would consider plants of smaller size and those not yet in operations.

Background:

Desalination (removal of ions from feedwater) is becoming an increasing large part of the water supply for many regions in the US. Desalination typically is a large energy user because of the high operating pressures. Worldwide, desalination has a much longer operating history than in the US. In addition, some plants have to be designed for very high power costs.

Research Approach:

The approach would include:

1. Compile operating and design information from planned and operating reverse osmosis plants.
2. Review their design and operational parameters.
3. Comparison a time of use design to conventional processes.

38. Identification and Evaluation of Innovative Water Treatment Processes

Description of Issue: Many new water concepts have been proposed. There is no process to actively identify innovative water treatment processes.

Benefits for Water and Wastewater Community: Without this investment, there will be no major advancement in water treatment techniques. This project will encourage revolutionary advancements in water treatment processes.

Objectives: There are several objectives:

1. Identify innovative water research ideas.
2. Evaluate the potential advantages/disadvantages of these ideas based upon scientific principals.
3. Assist in the demonstration of these processes.

Recommended Funding: The project cost is estimated \$150,000 for phase 1.

Past and Ongoing Related Research: The Bureau of Reclamation currently only evaluates ideas that are presented. This project would actively review new ideas.

Background:

Revolutionary new water treatment ideas require significant efforts by the developer. Often their ideas can not be commercialized because of lack of supporting data and interest in the water community. A means to assist in development of their ideas would be of great assistance in commercializing new ideas.

Research Approach:

A three phased approach is recommended:

Phase 1

1. Actively survey and solicit new water treatment ideas.
2. Screen ideas based upon scientific principals by a scientific advisory panel.
3. Rank and prioritize ideas based upon cost and development potential.
4. Recommend laboratory testing.

Phase 2

1. Laboratory testing for their future potential and quantify the operating parameters.
2. Evaluate the laboratory results based upon the energy usage and cost.
3. Rank the concepts based upon the laboratory results.
4. Recommend projects for pilot testing.

Phase 3

1. Conduct pilot testing.
2. Recommend technology demonstrations.

39. Digester Gas Storage for Improved Peak Power Management

Description of Issue: Diurnal storage of digester gas can provide improved power production at peak times for plants with turbines and/or fuel cells.

Benefits for Water and Wastewater Community: Power produced at peak times is of greater benefit for both the power producer and the grid.

Objective: For plants that are considering turbines and/or fuel cells, look at ways to optimize designs for peak shaving-optimization to improve return on investment and value to the grid of digester gas.

Recommended Funding: \$50K

Background: N/A

Research Approach:

Review existing research and technology options for storage.

40. Membrane Separation of Methane, Carbon Dioxide and Sulfides from Digester Gas

Description of Issue: Digester gas contains 60 to 65% methane with the remainder being carbon dioxide and traces of sulfide gases.

Benefits for Water and Wastewater Community: Enriching digester gas will increase the heating value and possibly make various energy recovery technologies (generators, fuel cells, etc.) more attractive. If digester gas is to be stored, enriching will increase BTU storage. An enriched gas might also make two-fuel engines more economical or feasible.

Objective: This project would determine the feasibility of using membranes to purify digester gas and determine potential benefits to wastewater treatment plants.

Recommended Funding: \$50,000 to \$150,000 for a one-year project to determine feasibility. If promising, funding in subsequent years and a cost-sharing partner will be requested for a demonstration project.

Past and Ongoing Related Research: Membrane manufacturers currently manufacture membranes for gas separation. They would be a good starting point for developing a membrane with the desired properties.

Potential Controversial Issues: Technology can be patented

Background:

Typical anaerobic digesters operating on wastewater derived solids produce 15 to 20 ft³ of biogas per pound of volatile solids destroyed. The gas is saturated with water vapor, but on a dry basis is 60 to 65% methane for a well operating digester. The remainder is carbon dioxide and sulfide gases. Large plants routinely burn the gas for digester heating and power generation. Small plants often use the gas only for heating and flare the rest. The availability of low cost, purified biogas might enable wider spread use of energy recovery and/or different energy recovery techniques

Research Approach:

Perform a literature survey and manufacturer survey to determine the availability of membranes for this purpose. After the feasibility is established, determine the potential benefits of the enriched gas stream for various energy recovery technologies such as gas engines, turbines and fuel cells. Finally determine the potential economic benefits and the requirements for a demonstration project at a wastewater treatment plant.

41. Ballasted Flocculation

Description of Issue: Ballasted flocculation is a physical-chemical process in which influent wastewater is screened, and heavy particles removed. It is usually used for treating wet weather flows due to its short residence time, fast start-up and small space requirements. However, the relatively high chemical (e.g., ferric chloride coagulant), sand and sludge disposal costs could be prohibitive.

Benefits for Water and Wastewater Community: Effective use of ballasted flocculation could result in integrated energy savings and regulatory compliance of wet weather flows.

Objective: The objective of this project would be to evaluate the design, efficiency, and energy consumption of ballasted flocculation systems and how they can alleviate the energy "work load" of the secondary system, particularly during wet weather flows.

Recommended Funding: \$200,000

Potential Controversial Issues: Obtaining proprietary information on certain commonly used pre-treatment chemicals could be difficult.

Background: N/A

Research Approach:

1. Survey types and application of various pre-treatment chemicals.
2. Study the mechanical system for optimizing the application of flocculants.
3. Select site and perform pilot testing.
4. Survey and benchmark available pre-treatment chemical usage and performance.

42. Use of Chlorine Dioxide and Ozone for Control of Disinfection By-Products in a Full-Scale Demonstration

Description of Issue: Ozone has replaced chlorine as a disinfectant at many treatment plants as a means of eliminating trihalomethanes. However, a number of other undesirable disinfection by-products emerged from this switch. In addition, production of ozone in ozone generators is energy intensive. Ozone also requires the creation of liquid oxygen at a cryogenic plant. The use of a preoxidant, such as chlorine dioxide (ClO₂) can potentially reduce energy use by reducing the use of ozone and also reduce disinfection by-products from ozone.

Benefits for Water and Wastewater Community: Depending on the optimum mix of ClO₂ and ozone to achieve disinfection goals, the water treatment plant will see savings from the reduction of ozone production. The benefits include reduction of disinfection by-products from using only ozone. The use of ClO₂ also may improve coagulation and settling prior to ozonation and minimize biological growth in flocculators and sedimentation basins.

Objective: This project would evaluate the energy savings from incorporating ClO₂ as a preoxidant necessary to achieve required reduction of disinfection by-products.

Recommended Funding: Total project cost is \$360,000. Requested funding is \$260,000 with match funding of \$100,000.

Past and Ongoing Related Research: A major benefit of ClO₂ treatment of drinking waters is that ClO₂ is an oxidizing agent rather than a chlorinating agent. As such, it does not chlorinate organic compounds except under conditions that are uncommon in water supplies. A few researchers have reported finding chlorinated organic compounds in water following ClO₂ applications, but these most likely were reaction products produced by trace quantities of free chlorine in the generated ClO₂ solutions (Gordon, 1992; Masschelein, 1979). The fact that ClO₂ is not a chlorinating agent accounts for its popularity as a way to minimize halogenated disinfection by-product concentrations in finished water without eliminating preoxidation from the treatment train. Richardson (1998) after lengthy, detailed studies of organic disinfection by-product formation following ClO₂ treatment of Ohio River water, isolated only a few chlorinated organic compounds, and these were present in the 1 ng/L to 10 ng/L range. She concluded that the production of organic-halogen compounds during ClO₂ treatment of drinking water was insignificant.

Potential Controversial Issues: ClO₂ is volatile and reactive. It is explosive at 5.8 psi or above atmospheric pressure at 6 psig. It cannot be compressed or stored and must be generated on site. Solutions generated for water treatment are in the range of 0.1 mg/L to 5.0 mg/L. If the aqueous concentration exceeds 10 g/L, an explosion may occur.

Background:

The application of a chemical preoxidant prior to ozonation offers particular benefits in potential energy savings. Previous experience has shown that the ozone dose can be reduced by approximately 25 percent in cases where ozone is being used as the primary disinfectant. Pilot plant studies at Las Vegas' 600-mgd facility show that the ozone dose required to achieve 2-log *Cryptosporidium* inactivation is reduced from 1.64 mg/L to 1.29 mg/L, a savings of 20 percent, when a small amount of chlorine is added prior to the ozone contactors. Results from Lincoln, Nebraska's full-scale ozone facility show that the ozone dose can be reduced from 2.0 mg/L to 1.5 mg/L during peak flow periods with low water quality when a preoxidant is used. As the energy use of an ozone system is directly proportional to the ozone dose, this approach can provide significant energy savings during periods of high power costs or low power availability.

Research Approach:

The project scope would include the following:

1. Determine the extent to which ClO₂ preoxidation of raw water will reduce ozone demand. Energy use and savings will be documented by comparison with the current baseline treatment scheme.

2. Determine the extent to which disinfection by products are formed following ozone treatment when ClO₂ is applied.
3. The testing period will be from six to nine months and will be timed to capture seasonal changes in raw water that lead to elevated concentrations. The appropriate ClO₂ dosages will be determined by demand studies and should range from 0.5 mg/L to no more than 1.0 mg/L. The project is to be conducted at full scale rather than pilot.

43. Using Advanced Controls and On-Line Instrumentation to Increase Capacity and Improve Performance and Energy Efficiency

Description of Issue: Many existing municipal water and wastewater treatment facilities in the U.S. were constructed in the 1970's and are now outdated or have reached maximum capacity. EPA has made a strong case for a multi-level approach to solving the looming infrastructure funding gap for water and wastewater systems, including improvements in asset management plans, system consolidation and innovative solutions.

Industrial facilities use a variety of advanced technologies such as state-of-the-art on-line instrumentation for real-time monitoring, advanced control algorithms, and statistical tools for process control and troubleshooting. These currently available technologies have yet to be fully adopted in the treatment and processing of municipal wastewater/water.

Benefits for Water and Wastewater Community: The Commission may want to develop a program to support the demonstration of advanced controls and on-line instrumentation to improve process performance and energy efficiency.

Objective: The program could provide an alternative to costly construction upgrades and could also provide some security enhancements. These advanced controls and information processing algorithms could also be used to take advantage of emerging real-time electric rates to reduce overall energy cost and reduce peak demand.

Recommended Funding: N/A

Background: N/A

Research Approach: N/A

**APPENDIX B
RESEARCH MATRIX, BUDGET & SCHEDULE**

AwwaRF/CEC Energy Research Roadmap Project List and Evaluation										
ID #	Project Description	Est. Budget (\$)	Estimated Project Timeline				Savings Potential *(1-3)	Success Likely? *(1-3)	Timeliness *(1-3)	Dot Vote Count
			2004	2005	2006	2007				
1	Review of International Desalination Research	\$70,000					3	3	3	5
2	Water and Wastewater Treatment Plant Energy Efficiency Achievement Program (annual funding required)	\$250,000					2	2	3	6
3	UV Optimization Guidance Manual	\$160,000					1	2	2	2
4	Dual Fueled Backup Generators (BUGS) for Reliability and Peak Shaving	\$500,000					3	3	3	3
5	Conversion of Digester Gas to Liquefied Natural Gas (LNG) and Liquefied Carbon Dioxide (LCO2)	\$7,000,000					1	2	3	3
6	Catalytic Advanced Oxidation Systems	\$150,000					2	3	2	1
7	Advanced Treatment of Delta Water to Meet Future Regulations	\$1,500,000					1	2	3	3
8	Development of a Utility Energy Index to Assist in Benchmarking of Energy Management for Water and Wastewater Utilities	\$250,000	18 mo.				3	2	3	5
9	Best Forecasting Tools for Predicting Water Demands for Energy Optimization of Pumping Plants	\$250,000					2	3	3	1
10	Energy Consumption of Ultraviolet and Chlorine/Sodium Hypochlorite Disinfection	\$100,000					1	2	3	0
11	Development of In-line, Continuous Thermal Hydrolysis for Improving Municipal Sludge Digestion	\$600,000					3	2	3	4

ID #	Project Description	Est. Budget (\$)	Estimated Project Timeline				Savings Potential *(1-3)	Success Likely? *(1-3)	Timeliness *(1-3)	Dot Vote Count
			2004	2005	2006	2007				
12	Use of Membranes for Treatment of Biosolids Processing Recycles	\$700,000					3	2	3	2
13	Development of High Solids, Vertical, Plug Flow Anaerobic Digestion	\$850,000					2	2	2	0
14	Cost-Effective Digester Gas Cleanup for Advanced Power Generation	\$500,000					2	3	3	5
15	Energy Optimization of Thermophilic Anaerobic Digestion for Class A Biosolids Production	\$500,000					2	3	3	4
16	Gas Enhancement During Anaerobic Process of Sewage Sludge by Codigestion of Organic Solid Wastes	\$550,000					2	2	3	5
17	Estimation of Embedded Energy in Water	\$200,000					1	3	3	3
18	Development of Anaerobic Treatment Technologies for Municipal Wastewater Treatment	\$1,000,000					3	2	2	2
19	Development of Customized Pretreatment and Diversion Program	\$200,000					1	1	1	1
20	UV Disinfection: Develop Next Generation Energy Efficient UV Disinfection Systems for Water and Wastewater Treatment	\$75,000					1	1	1	0
21	Explore Options for Decentralized and Small-Scale Wastewater Treatment Systems that are Energy Efficient	\$250,000					3	3	2	4
22	Enhancing BOD and SS Removal Prior to the Activated Sludge Process in WWTPs.	\$600,000					3	2	2	4
23	Waste Activated Sludge Conditioning Prior to Anaerobic Digestion to Enhance Treatability and Dewatering	\$600,000					3	2	3	1
24	Barriers to Using Fine Pore Aeration Systems at Small Treatment Plants	\$100,000					3	3	3	2
25	Recovery and Use of Digester Gas at Small Wastewater Treatment Plants	\$100,000					2	3	3	2

ID #	Project Description	Est. Budget (\$)	Estimated Project Timeline				Savings Potential *(1-3)	Success Likely? *(1-3)	Timeliness *(1-3)	Dot Vote Count
			2004	2005	2006	2007				
26a	Guidance Manual: Protecting Treated Water Quality While Reducing Energy Costs	\$250,000					1	3	3	4
26b	Guidance Manual: Protecting Distribution System Water Quality While Reducing Energy Costs	\$250,000					1	3	3	3
27	Energy Consumption for Potable Water Conveyance and Treatment in Southern California Region	\$150,000					1	3	3	3
28	Primary Effluent Microfiltration - Secondary Treatment Alternative	\$2,000,000					3	1	2	2
29	Compare Electrodialysis Reversal (EDR) Costs and Performance to Low and High Pressure Reverse Osmosis (RO) Systems for Desalination	\$100,000					2	1	3	0
30	Peracetic Acid Pilot Study for Effluent Disinfection	\$1,000,000					2	1	1	1
31	Recuperative Thickening Anaerobic Digestion for Enhanced Gas Production	\$300,000					3	2	2	1
32	Energy Efficient, Carbon Efficient Advanced Wastewater Treatment for Natural Systems	\$500,000					3	3	3	4
33	Zero Liquid Discharge for In-Land Desalination	\$500,000					3	2	3	6
34	The Cost and Value of Recycled Water	\$250,000					3	2	3	6
35	Development of Recycled Water Quality Indicators for Reclaimed Waters Used for Ground Water Recharge	\$1,000,000					2	2	2	1
36	Thermodynamic Evaluation of Advanced Water and Wastewater Treatment Technologies	\$250,000					2	3	3	2
37	Development of a Guidance Manual to Design/Operate Desalination Facilities for Maximum Energy Efficiency	\$150,000					2	3	3	2
38	Identification and Evaluation of Innovative Water Treatment Processes	\$150,000					3	1	1	3
39	Energy Generation & Recovery: Digester Gas Storage for Improved Peak Power Management	\$50,000					1	2	2	0

ID #	Project Description	Est. Budget (\$)	Estimated Project Timeline				Savings Potential *(1-3)	Success Likely? *(1-3)	Timeliness *(1-3)	Dot Vote Count
			2004	2005	2006	2007				
40	Membrane Separation of Methane, Carbon Dioxide and Sulfides from Digester Gas	\$95,000					1	2	2	0
41	Ballasted Flocculation	\$200,000					**	**	**	3
42	Use of Chlorine Dioxide and Ozone for Control of Disinfection By-Products in a Full-Scale Demonstration	**					**	**	**	**
43	Using Advanced Controls and On-line Instrumentation to Increase Capacity, and Improve Performance and Energy Efficiency	**					**	**	**	**
* Rating Guidelines for a Project's Savings Potential, Likelihood for Success, and Timeliness: 1= Low, 2= Moderate, 3= High **Not Rated										

**APPENDIX C
WORKSHOP AGENDA**

California Energy Commission/AwwaRF

Water and Wastewater Energy Efficiency

Research Needs Workshop

Sacramento, CA
February 25-26, 2003

Objective: The goal of this workshop is to prepare a Water and Wastewater Energy Efficiency Roadmap to identify and prioritize projects to focus on emerging technologies and best practices that improve the energy efficiency, reliability and costs for water and wastewater treatment facilities.

Day 1, February 25

7:00 – 8:00	Breakfast - Atrium	
8:00 – 8:15	Introductions - Shasta Rooms A &	Reekie/Roggensack
8:15 – 8:30	Welcome	Surles
8:30 – 9:45	Introduction/agenda/approach	Means
9:45 – 10:15	Energy efficiency opportunities	Carns
10:15 – 10:30	Break	
10:30 – 11:30	Review of research ideas	Group
11:30 – 12:00	Identification of research areas/gaps	Group
12:00 – 12:15	Establish breakout groups/chairpersons	Means

Review research template

12:15 – 1:15

Lunch- Atrium

1:15 – 5:00

*Begin writing project descriptions-
Shasta, Cabernet & Chardonnay Rooms Breakout*

5:00

Adjourn

6:00

Reception-Atrium

7:00

Dinner-Brandywine Room

Group

Day 2, February 26

7:15 – 8:00

Continental buffet breakfast -Eagle Room

8:00 – 8:15

Review of Day 1/Day 2 approach Means

8:15 – 11:30

*Continue refining project descriptions-
Eagle, Cabernet & Berryessa Rooms Breakout*

11:30 – 12:30

Lunch -Atrium

12:30 – 1:30

Review budgets/schedule/priority Breakout

1:30 – 3:30

*Group report out on projects/funding level/priority
-Eagle Room Spokespersons*

3:30 – 3:45

Break

3:45 – 4:15

Group prioritization exercise-Eagle Room Group

4:15 - 4:30

Wrap up

Means/Reekie/Roggensack

4:30

Adjourn

APPENDIX D WORKSHOP PARTICIPANT LIST

Invitees for AwwaRF Energy Workshop Water and Wastewater Engery Efficiency Roadmap Workshop				
Name		Organization	General Number	E-mail
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Project Team				
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Chaudry	Shahid	California Energy Commission		schaudhr@energy.state.ca.us

APPENDIX E

BROAD ENERGY ISSUES ADDRESSED BY ROADMAP

The Water and Wastewater Energy Efficiency Workshop identified eight general areas of research that the participants determined would be the most effective in solving energy issues for the water and wastewater industries. These eight general areas are discussed in the body of this report, and are as follows:

1. Advanced treatment processes
2. Desalination
3. Energy generation and recovery
4. Societal and institutional issues
5. Energy optimization
6. Sustainability
7. Decentralization
8. Total energy management

These eight research areas address five key issues that are the mission of the PIER program administered by the California Energy Commission. An issue under the PIER program is defined as a broad statement of a problem for which resolution is essential to reduce the cost or improve the reliability and availability of energy. These issues as they apply to the water and wastewater industries are as follows:

1. Rising electricity costs to meet stringent water quality requirements
2. Rising electricity costs to enhance water supplies
3. Improving reliability to mitigate problems of grid and restructuring
4. Lack of a system-level energy-water link perspective for increasing energy efficiency
5. Non-technical barriers to optimize energy use and to foster energy savings

Relationship Between Research Areas and Key Issues

While each of the eight general areas will address all the energy issues that pertain to water and wastewater treatment to some extent, the research areas that most directly address the issues are as follows:

Issue: Rising electricity costs to meet stringent water quality requirements

- Advanced treatment processes
- Energy optimization
- Total energy management
- Decentralization
- Sustainability

Issue: Rising electricity costs to enhance water supplies

- Advanced treatment processes
- Desalination
- Decentralization
- Sustainability

Issue: Improved reliability to mitigate problems of grid and restructuring

- Energy generation and recovery
- Energy optimization
- Total energy management
- Decentralization

Issue: Lack of a system-level energy-water link perspective for increasing energy efficiency

- Total energy management
- Energy optimization
- Societal and institutional issues

Issue: Non-technical barriers to optimize energy use and to foster energy savings

- Societal and institutional issues
- Decentralization

Development of Targets and Approaches from Proposed Projects

The workshop participants provided 44 proposed projects that offer potential solutions to energy needs within the eight general research areas. These proposed projects provide inherent targets and approaches to meet the five issues. These targets and approaches are related to the needs and potential solutions discussed in the report according to the flow chart in [Figure E.1](#).

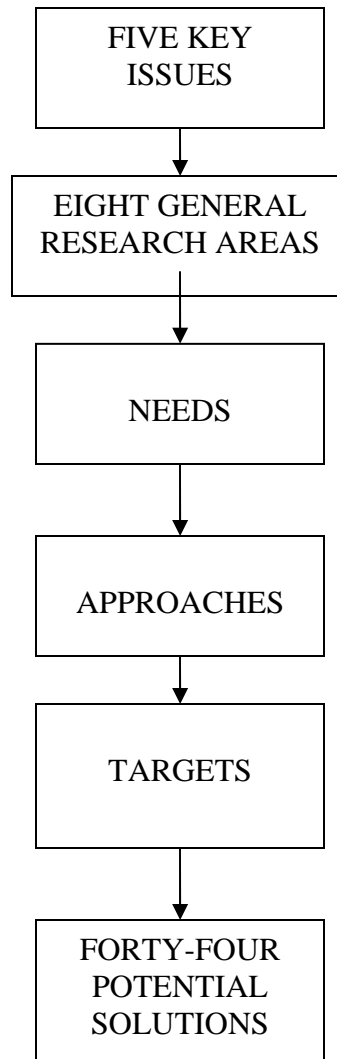


Figure E.1: Approach for the Development of Proposed Projects

The following tables summarize targets and approaches derived from the proposed project within each general research area.

ADVANCED TREATMENT PROCESSES

NEED	TARGET	APPROACH	POTENTIAL SOLUTION
Alternative disinfection systems for microbially and chemically challenged water and wastewater including ozone, UV, chlorine dioxide and gaseous/liquid chlorine	Optimized energy efficient UV systems for water and wastewater	Develop UV guidance manual and improve training for staff	#3: UV Optimization Guidance Manual #20: UV Disinfection: Develop Next-Generation Energy Efficient UV Disinfection Systems for Water and Wastewater Treatment
	Sophisticated treatment processes to meet changes in source waters	Examine synergistic effect of multiple process technologies	#7: Advanced Treatment of Delta Water to Meet Future Regulations
	Energy efficient and environmentally friendly alternatives to chlorine and UV disinfection processes	Evaluate and demonstrate the effectiveness of alternatives to conventional disinfection, such as the use of peracetic acid	#30: Peracetic Acid Pilot Study for Effluent Disinfection
	Energy efficient technologies to control disinfection by-products	Determine energy savings from incorporating preoxidants to reduce the use of ozone	#42: Use of Chlorine Dioxide and Ozone for Control of Disinfection By-Products in a Full-Scale Demonstration
Energy efficient advanced oxidation for organic compounds in water and wastewater	Energy efficient technologies for removing organic compounds	Design and develop advanced oxidation processes	#6: Catalytic Advanced Oxidation Systems
Advanced, energy efficient treatment technologies for biosolids	Reduced energy requirements of treating biosolids	Develop membrane systems to filter high concentrations of ammonia, phosphorous, alkalinity, TDS and hardness from recycle streams to biosolids treatment processes	#12 Use of Membranes for Treatment of Biosolids Processing Recycles
Biological treatment technologies (e.g. anaerobic/aerobic membrane bioreactors, biological nutrient removal) for wastewater	Conversion to anaerobic treatment for wastewater	Design, develop and test anaerobic reactor for wastewater	#18: Development of Anaerobic Treatment Technologies for Municipal Wastewater Treatment
Separation technologies including membrane filtration for primary treatment and secondary treatment	Conversion to anaerobic treatment for wastewater	Design, develop and test anaerobic reactor for wastewater	#18: Development of Anaerobic Treatment Technologies for Municipal Wastewater Treatment
Advanced primary treatment	Reduced energy requirements of activated sludge secondary treatment process	Study and test membrane filtration on primary effluent as a means of reducing sludge production and energy requirements	#28: Primary Effluent Microfiltration – Secondary Treatment Alternative
Solids handling (dewatering optimization)	Increased use of digester gas	Conduct bench scale testing and build a pilot plant to determine configuration, operating parameters and cost-benefit of a plug flow anaerobic digester	#13 Development of High Solids, Vertical, Plug Flow Anaerobic Digestion
		Conduct pilot plant demonstration of recuperative thickening process on an anaerobic digester to increase solids retention time without increasing hydraulic retention time	#31 Recuperative Thickening of Anaerobic Digestion for Enhanced Gas Production
	Lower energy requirements for dewatering sludge	Investigate technologies to improve breakdown of waste activated sludge	#23 Waste Activated Sludge Conditioning Prior to Anaerobic Digestion to Enhance Treatment and Dewatering

ADVANCED TREATMENT PROCESSES (Continued)

Advanced digestion technologies	Conversion to anaerobic treatment for wastewater	Design, develop and test anaerobic reactor for wastewater	#18: Development of Anaerobic Treatment Technologies for Municipal Wastewater Treatment
Synergistic effects of treatment processes in reducing energy consumption	Improved water reclamation and recycling technologies	Demonstrate and quantify energy efficiency and environmental benefits of advanced natural systems for primary, secondary and tertiary treatment of wastewater	#32: Energy-Efficient, Carbon-Efficient Alternative Advanced Wastewater Treatment
Energy use impacts due to regulatory requirements (discharge and water delivery)	Sophisticated treatment processes to meet changes in source waters	Examine synergistic effect of multiple process technologies	#7: Advanced Treatment of Delta Water to Meet Future Regulations
Energy implications of new technologies to meet stringent arsenic standards			*

DESALINATION

NEED	TARGET	APPROACH	POTENTIAL SOLUTION
Characterization and evaluation of new or emerging technologies	Knowledge of research efforts on desalination from other parts of the world	Develop a reference document containing current research and development efforts of the international desalination community	#1: Review of International Desalination Research
Assessment of the water resource potential of brackish groundwater/wastewater	Low energy, cost effective options for disposing desalination concentrate from in-land desalination facilities	Develop test program to evaluate innovative technologies to remove toxic components from desalination concentrate	#33: Zero Liquid Discharge for In-Land Desalination
Improvements in membrane performance including the development of lower pressure membranes (e.g. reduce fouling, increase flux, improve rejection, increase integrity, increased longevity, etc.)	Cost comparisons between electrodialysis reversal and low and high pressure reverse osmosis treatment	Conduct detailed, commissioned study on all capital, energy and operation and maintenance costs on electrodialysis reversal and low and high pressure reverse osmosis treatment	#29: Comparison of Electrodialysis Reversal (EDR) Costs and Performance to Low and High Pressure Reverse Osmosis (RO) Systems for Desalination
Pre-treatment systems	Improved operation of desalination facilities based on electric rate structures	Develop a guidance manual to design and operate desalination facilities for maximum energy efficiency	#37: Development of a Guidance Manual to Design/Operate Desalination Facilities for Maximum Energy Efficiency
Post-treatment systems	Low energy, cost effective options for disposing desalination concentrate from in-land desalination facilities	Develop test program to evaluate innovative technologies to remove toxic components from desalination concentrate	#33: Zero Liquid Discharge for In-Land Desalination
	Improved operation of desalination facilities based on electric rate structures	Develop a guidance manual to design and operate desalination facilities for maximum energy efficiency	#37: Development of a Guidance Manual to Design/Operate Desalination Facilities for Maximum Energy Efficiency
Concentrate treatment and disposal strategies	Low energy, cost effective options for disposing desalination concentrate from in-land desalination facilities	Develop test program to evaluate innovative technologies to remove toxic components from desalination concentrate	#33: Zero Liquid Discharge for In-Land Desalination

DESALINATION (Continued)

Improvements in thermal processes			*
Improvements in electrodialysis technology	Cost comparisons between electrodialysis reversal and low and high pressure reverse osmosis treatment	Conduct detailed, commissioned study on all capital, energy and operation and maintenance costs on electrodialysis reversal and low and high pressure reverse osmosis treatment	#29: Comparison of Electrodialysis Reversal (EDR) Costs and Performance to Low and High Pressure Reverse Osmosis (RO) Systems for Desalination
Strategies to speed the development and adoption of new technologies	Knowledge of research efforts on desalination from other parts of the world	Develop a reference document containing current research and development efforts of the international desalination community	#1: Review of International Desalination Research
Strategies to speed the commoditization of membranes			*

ENERGY GENERATION AND RECOVERY

NEED	TARGET	APPROACH	POTENTIAL SOLUTION
Investigate and demonstrate the ability to recover previously lost energy resources	Increased use of digester gas	Determine the costs and benefits to install liquification systems to convert digester gas to liquefied natural gas and carbon dioxide	#5 Conversion of Digester Gas to Liquefied Natural Gas and Liquefied Carbon Dioxide
		Research high temperature hydrolysis to improve anaerobic digestion and increase production of digester gas and energy recovery	#11 Development of In-Line, Continuous Thermal Hydrolysis for Improving Municipal Sludge Digestion
		Conduct bench scale testing and build a pilot plant to determine configuration, operating parameters and cost-benefit of a plug flow anaerobic digester	#13 Development of High Solids, Vertical, Plug Flow Anaerobic Digestion
		Determine barriers that prevent small wastewater treatment plants from recovering more energy from digester gas	#25 Recovery and Use of Digester Gas at Small Wastewater Treatment Plants
Maximize the value of existing infrastructure (use of standby generation)			*
Blending energy resources			*
Supplementing digester feed with non-wastewater solids	Increased use of digester gas	Evaluate the feasibility of co-digesting other organic wastes with sewage sludge to enhance digester gas production	#16 Gas Enhancement During Anaerobic Process of Sewage Sludge by Co-digestion of Organic Solid Wastes
Dual fuel, backup power	Increased back-up generation sources	Establish specifications to convert existing diesel generators into dual fueled back-up generators using methane injection systems	#4 Dual Fueled Backup Generators (BUGS) for Reliability and Peak Shaving

ENERGY GENERATION AND RECOVERY (continued)

NEED	TARGET	APPROACH	POTENTIAL SOLUTION
Biogas cleanup	Reduce sulfur, halogenated hydrocarbons and siloxanes that harmful to post combustion emission control equipment	Develop a cost effective, small scale, commercial digester gas cleanup system	#14 Cost Effective Digester Gas Cleanup for Advanced Power Generation
Balancing on-site generation with grid support	Increased use of digester gas	Increase digester gas storage for peak power management	#39 Digester Gas Storage for Improved Peak Power Management
In-line hydroelectric			*
Energy recovery and membranes	Increased use of digester gas	Study the feasibility of using membranes to enrich digester gas for increasing the heating value for energy generation and storage	#40 Membrane Separation of Methane and Carbon Dioxide and Sulfides from Digester Gas
Cogeneration			*
Power system integration			*
Interconnections			*
Improve the efficiency and cost effectiveness of energy production	Lower energy requirements for dewatering sludge	Investigate technologies to improve breakdown of waste activated sludge	#23 Waste Activated Sludge Conditioning Prior to Anaerobic Digestion to Enhance Treatment and Dewatering
	Increased use of digester gas	Determine barriers that prevent small wastewater treatment plants from recovering more energy from digester gas	#25 Recovery and Use of Digester Gas at Small Wastewater Treatment Plants
		Conduct pilot plant demonstration of recuperative thickening process on an anaerobic digester to increase solids retention time without increasing hydraulic retention time	#31 Recuperative Thickening of Anaerobic Digestion for Enhanced Gas Production
		Study the feasibility of using membranes to enrich digester gas for increasing the heating value for energy generation and storage	#40 Membrane Separation of Methane and Carbon Dioxide and Sulfides from Digester Gas
Reduce the impacts of energy production			*
Improve the reliability and security of energy sources			*
Improve energy conservation and recovery			*
Develop renewable energy sources (other than digester gas)			*

SOCIETAL AND INSTITUTIONAL ISSUES

NEED	TARGET	APPROACH	POTENTIAL SOLUTION
Develop understanding of energy implications of alternative water resource strategies	Methodology for estimating embedded energy use associated with water and wastewater treatment	Build a database and conduct analysis to develop matrix to correlate water development and consumption to energy use	#17 Estimation of Embedded Energy in Water
	Implement most cost effective solution between imported and local water supplies in Southern California	Identify the range of energy use of water conveyance and treatment for all options	#27 Energy Consumption for Potable Water Conveyance and Treatment in Southern California Region
	Increase use of recycled and reclaimed water	Conduct study and analysis to determine energy and environmental savings from recycled and reclaimed water	#34 The Cost and Value of Recycled Water
Identify institutional barriers to infrastructure finance			*
Provide zero interest financing for innovative ideas and advanced technologies			*
Pollution offset credits			*
Co-funding of energy savings programs through rates or incentives			*
Encouraging application of new or emerging technologies	Increased incentives for energy efficiency	Institute benchmarks, goals, marketing and plant reviews for facility operations to establish energy efficiency achievement programs	#2 Water and Wastewater Treatment Plant Energy Efficiency Achievement Program
	Increase innovation of water treatment processes	Develop a project to actively review, identify, evaluate and demonstrate new and innovative treatment processes	#38 Identification and Evaluation of Innovative Water Treatment Processes
Conduct demonstration projects	Increase innovation of water treatment processes	Develop a project to actively review, identify, evaluate and demonstrate new and innovative treatment processes	#38 Identification and Evaluation of Innovative Water Treatment Processes
Develop Best Management Practices for industrial customers	Reduced loadings to wastewater treatment facilities	Customize pretreatment, recycling and diversion programs for upstream industrial and residential users	#19 Development of Customized Pre-Treatment and Diversion Programs
Consider energy implications and cross-media impacts of regulations	Water quality protection in treatment plants and distribution systems when implementing energy management practices	Develop a guidance manual to effectively manage energy and potential water quality risks	#26a Guidance Manual: Protecting Treated Water Quality While Reducing Energy Costs
			#26b Guidance Manual: Protecting Distribution System Water Quality While Reducing Energy Costs

ENERGY OPTIMIZATION

NEED	TARGET	APPROACH	POTENTIAL SOLUTION
Pump and motor optimization			*
Automation strategies	Advanced controls and on-line instrumentation to improve performance and energy efficiency	Apply state-of-the-art on-line instrumentation for real-time monitoring, advanced control algorithms and statistical tools for process control and troubleshooting used in industrial facilities to water and wastewater treatment facilities	#43 Process Optimization: Using Advanced Controls and On-Line Instrumentation to Increase Capacity, Improve Performance and Improve Energy Efficiency
Real-time monitoring and control systems	Advanced controls and on-line instrumentation to improve performance and energy efficiency	Apply state-of-the-art on-line instrumentation for real-time monitoring, advanced control algorithms and statistical tools for process control and troubleshooting used in industrial facilities to water and wastewater treatment facilities	#43 Process Optimization: Using Advanced Controls and On-Line Instrumentation to Increase Capacity, Improve Performance and Improve Energy Efficiency
On-line instrumentation and improved sensors	Advanced controls and on-line instrumentation to improve performance and energy efficiency	Apply state-of-the-art on-line instrumentation for real-time monitoring, advanced control algorithms and statistical tools for process control and troubleshooting used in industrial facilities to water and wastewater treatment facilities	#43 Process Optimization: Using Advanced Controls and On-Line Instrumentation to Increase Capacity, Improve Performance and Improve Energy Efficiency
Development of decision support tools	Accurate forecasting tools to predict water demands for pumping plants	Evaluate, test and rank available methods and programs for making water demand predictions	#9 Best Forecasting Tools for Predicting Water Demands for Energy Optimization of Pumping Plants
	Cost-effective, energy efficient disinfections systems	Survey and perform an integrated energy and life-cycle costing analysis of UV, chlorine/sodium hypochlorite and other disinfection systems to be compiled into a guidance manual	#10 Energy Consumption of UV and Chlorine/Sodium Hypochlorite Disinfection
	Guidance and understanding of energy consumption for unit operations	Conduct a thermodynamic evaluation of advanced treatment technologies for water and wastewater processes	#36 Thermodynamic Evaluation of Advanced Water and Wastewater Treatment Technologies
Power generation and pump storage optimization	Increased back-up generation sources	Establish specifications to convert existing diesel generators into dual fueled back-up generators using methane injection systems	#4 Dual Fueled Backup Generators (BUGS) for Reliability and Peak Shaving
Water conveyance optimization	Accurate forecasting tools to predict water demands for pumping plants	Evaluate, test and rank available methods and programs for making water demand predictions	#9 Best Forecasting Tools for Predicting Water Demands for Energy Optimization of Pumping Plants

ENERGY OPTIMIZATION (continued)

NEED	TARGET	APPROACH	POTENTIAL SOLUTION
Primary wastewater treatment optimization	Increased BOD and suspended solids removal prior to activated sludge processes	Enhance performance of primary clarifiers or replace primary clarifiers with more effective processes	#22 Enhancing Biological Oxygen Demand and Suspended Solids Removal Prior to the Activated Sludge Process in Wastewater Treatment Plants
Biological process optimization to save energy	Increased use of fine pore aeration systems for secondary treatment at small wastewater treatment plants	Survey small wastewater treatment plants, identify barriers that do not exist for large wastewater treatment plants and determine solutions to increase use of fine pore aeration at small plants	#24 Barriers to Using Fine Pore Aeration Systems at Small Treatment Plants
	Improved water reclamation and recycling technologies	Demonstrate and quantify energy efficiency and environmental benefits of advanced natural systems for primary, secondary and tertiary treatment of wastewater	#32 Energy-Efficient, Carbon- Efficient Advanced Wastewater Treatment for Natural Systems
Waste activated sludge optimization to reduce biosolids production	Lower energy requirements for dewatering sludge	Conduct bench scale testing and build a pilot plant to determine configuration, operating parameters and cost-benefit of a plug flow anaerobic digester	#13 Development of High Solids, Vertical Plug Flow Anaerobic Digestion
		Investigate technologies to improve breakdown of waste activated sludge	#23 Waste Activated Sludge Conditioning Prior to Anaerobic Digestion to Enhance Treatability and Dewatering
		Conduct pilot plant demonstration of recuperative thickening process on an anaerobic digester to increase solids retention time without increasing hydraulic retention time	#31 Recuperative Thickening of Anaerobic Digestion for Enhanced Gas Production
Biosolids digestion optimization	Increased use of digester gas	Research high temperature hydrolysis to improve anaerobic digestion and increase production of digester gas and energy recovery	#11 Development of In-Line, Continuous Thermal Hydrolysis for Improving Municipal Biosolids Digestion
		Conduct bench scale testing and build a pilot plant to determine configuration, operating parameters and cost-benefit of a plug flow anaerobic digester	#13 Development of High Solids, Vertical Plug Flow Anaerobic Digestion
		Conduct pilot plant demonstration of recuperative thickening process on an anaerobic digester to increase solids retention time without increasing hydraulic retention time	#31 Recuperative Thickening of Anaerobic Digestion for Enhanced Gas Production
	Reduced energy requirements for thermophilic anaerobic digestion processes for Class A biosolids production	Conduct laboratory assays, pilot scale and full scale digester tests to determine optimum temperature for solids destruction, methane production, odor reduction and disinfection of sewage sludge	#15 Energy Optimization of Thermophilic Anaerobic Digestion for Class A Biosolids Production

ENERGY OPTIMIZATION (continued)

NEED	TARGET	APPROACH	POTENTIAL SOLUTION
Development of reservoir operational models to maximize energy efficiency			*
Development of resource balancing models and management tools	Increased incentives for energy efficiency	Institute benchmarks, goals, marketing and plant reviews for facility operations to establish energy efficiency achievement programs	#2 Water and Wastewater Treatment Plant Energy Efficiency Achievement Program
	Increased application of best management practices for energy	Develop energy index to measure and assess energy management at water and wastewater facilities	#8 Development of a Utility Energy Index to Assist in Benchmarking of Energy Management for Water and Wastewater Utilities

SUSTAINABILITY

NEED	TARGET	APPROACH	POTENTIAL SOLUTION
Cross- media pollution and impact reduction (greenhouse gas emissions from energy use and methane production, groundwater basin salinity)	Increased use of digester gas	Determine the costs and benefits to install liquification systems to convert digester gas to liquefied natural gas and carbon dioxide	#5 Conversion of Digester Gas to Liquefied Natural Gas and Liquefied Carbon Dioxide
		Develop a cost effective, small scale, commercial digester gas cleanup system	#14 Cost Effective Digester Gas Cleanup for Advanced Power Generation
	Energy efficient and environmentally friendly alternatives to chlorine and UV disinfection processes	Evaluate and demonstrate the effectiveness of alternatives to conventional disinfection, such as the use of peracetic acid	#30 Peracetic Acid Pilot Study for Effluent Disinfection
Water use efficiency including conservation policy and practice and water recycling	Reduced loadings to wastewater treatment facilities	Customize pretreatment, recycling and diversion programs for upstream industrial and residential users	#19 Development of Customized Pretreatment and Diversion Programs
Water reuse policy and practice	Increase use of recycled and reclaimed water	Conduct study and analysis to determine energy and environmental savings from recycled and reclaimed water	#34 The Cost and Value of Recycled Water
Aquifer storage and recharge	Maintained use of reclaimed water as a source for ground water recharge	Develop a scientifically based quality indicator for reclaimed water that is to be used for recharging ground water	#35 Development of Recycled Water Quality Indicators for Reclaimed Waters Use for Groundwater Recharge

SUSTAINABILITY (Continued)

NEED	TARGET	APPROACH	POTENTIAL SOLUTION
Stormwater management and nonpoint source pollution control	Reduced energy requirements of secondary treatment systems during wet weather flows	Optimize design and application of chemicals for ballasted flocculation systems	#41 Ballasted Flocculation
Using and improving existing technology or best available technology	Cost-effective, energy efficient disinfections systems	Survey and perform an integrated energy and life-cycle costing analysis of UV, chlorine/sodium hypochlorite and other disinfection systems to be compiled into a guidance manual	#10 Energy Consumption of UV and Chlorine/Sodium Hypochlorite Disinfection
	Reduced energy requirements of treating biosolids	Develop membrane systems to filter high concentrations of ammonia, phosphorous, alkalinity, TDS and hardness from recycle streams to biosolids treatment processes	#12 Use of Membranes for Treatment of Biosolids Processing Recycles
	Conversion to anaerobic treatment for wastewater	Design, develop and test anaerobic reactor for wastewater	#18 Development of Anaerobic Treatment Technologies for Municipal Wastewater Treatment
Reducing chemical usage	Improved water reclamation and recycling technologies	Demonstrate and quantify energy efficiency and environmental benefits of advanced natural systems for primary, secondary and tertiary treatment of wastewater	#32 Energy-Efficient, Carbon-Efficient Advanced Wastewater Treatment for Natural Systems
	Reduced energy requirements of secondary treatment systems during wet weather flows	Optimize design and application of chemicals for ballasted flocculation systems	#41 Ballasted Flocculation
Methods to facilitate adoption of emerging technologies			*

DECENTRALIZATION

TARGET	APPROACH	POTENTIAL SOLUTION
Information on energy savings of decentralized systems over transport and treatment of wastewater to large wastewater treatment plants	Develop a model to predict energy use and cost of capital and operation and maintenance of a variety of decentralized wastewater collection and treatment systems	#21 Explore Options for Decentralized and Small-Scale Wastewater Treatment Systems that are Energy Efficient
Increased use of fine pore aeration systems for secondary treatment at small wastewater treatment plants	Survey small wastewater treatment plants, identify barriers that do not exist for large wastewater treatment plants and determine solutions to increase use of fine pore aeration at small plants	#24 Barriers to Using Fine Pore Aeration Systems at Small Treatment Plants
Increased use of digester gas	Determine barriers that prevent small wastewater treatment plants from recovering more energy from digester gas	#25 Recovery and Use of Digester Gas at Small Wastewater Treatment Plants

TOTAL ENERGY MANAGEMENT

NEED	TARGET	APPROACH	POTENTIAL SOLUTION
"Energy Star" or ISO certification with incentives	Increased incentives for energy efficiency	Institute benchmarks, goals, marketing and plant reviews for facility operations to establish energy efficiency achievement programs	#2 Water and Wastewater Treatment Plant Energy Efficiency Achievement Program
Baseline and self-evaluation criteria	Increased application of best management practices for energy management	Develop energy index to measure and assess energy management at water and wastewater facilities	#8 Development of a Utility Energy Index to Assist in Benchmarking of Energy Management for Water and Wastewater Utilities
	Water quality protection in treatment plants and distribution systems when implementing energy management practices	Develop a guidance manual to effectively manage energy and potential water quality risks	#26a Guidance Manual: Protecting Treated Water Quality While Reducing Energy Costs #26b Guidance Manual: Protecting Distribution System Water Quality While Reducing Energy Costs
Direct energy use related to water and wastewater service provision	Guidance and understanding of energy consumption for unit operations	Conduct a thermodynamic evaluation of advanced treatment technologies for water and wastewater processes	#36 Thermodynamic Evaluation of Advanced Water and Wastewater Treatment Technologies
Indirect energy use related to water and wastewater service provision			*
Whole system analysis methods	Methodology for estimating embedded energy use associated with water and wastewater treatment	Build a database and conduct analysis to develop matrix to correlate water development and consumption to energy use	#17 Estimation of Embedded Energy in Water
	Implement most cost effective solution between imported and local water supplies in Southern California	Identify the range of energy use of water conveyance and treatment for all options	#27 Energy Consumption for Potable Water Conveyance and Treatment in Southern California Region
Real time energy monitoring			*
Demand management and integrating peaks	Increased use of digester gas	Increase digester gas storage for peak power management	#39 Digester Gas Storage for Improved Peak Power Management

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ABBREVIATIONS

ABR	anaerobic baffled reactor
AGF	anoxic gas flotation
AIWPS	advanced integrated wastewater pond system
AOPs	advanced oxidation processes
AS	activated sludge
ASCE	American Society of Civil Engineering
AWWA	American Water Works Association
AwwaRF	Awwa Research Foundation
BACT	best available control technology
BOD	biochemical oxygen demand
BTU	British thermal unit
BUGS	backup generators
CCWD	Contra Costa Water District
CEPT	chemically enhanced primary treatment
CFR	Code of Federal Regulations
CD-ROM	compact disc-read only memory
CUWA	California Urban Water Agencies
CWA	Clean Water Act
DDBP	disinfection and disinfection by-product
D/E	diatomaceous earth
EDR	electrodialysis reversal
EIS	energy systems integration
EPAG	environmentally preferred advanced generation
EPRI	Electric Power Research Institute
EWQMS	energy water quality management systems
FOG	fat, oil, grease
ft ³	cubic foot
g/L	gram per liter
GWh	gigawatt hour
ISO	International Organization for Standardization
IWA	industrial/agricultural/water
KWh/ac-ft	kilowatt hour per acre foot
kWh/af	kilowatt hour per acre foot
kwh/d	kilowatt hour per day

LNG	liquefied natural gas
MG	million gallons
MGD	million gallons per day
mg/L	milligram per liter
MF	microfiltration
MTBE	methyl tert butyl ether
NDMA	n-nitrosodimethylamine
nm	nanometer
NPV	net present value
NWRI	National Water Research Institute
NYSERDA	New York State Energy Development Authority
O&M	operations and maintenance
OFMSW	organic fraction of municipal solid waste
PIER	Public Interest Energy Research Program
RD&D	research, development, and demonstration
RFP	request for proposals
RO	reverse osmosis
ROI	return on investment
SCADA	supervisory control and data acquisition
SC-AQMD	South Coast Air Quality Management District
scf/d	standard cubic feet per day
SCR	selective catalytic reduction
SS	suspended solids
STEP/STEG	septic tank effluent pumping/gravity
TEM	total energy management
TOC	total organic carbon
TSS	total suspended solids
U.S.	United States
UF	ultrafiltration
USEPA	United States Environmental Protection Agency
UV	ultraviolet
VOC	volatile organic contaminant
WAS	waste activated sludge
WEF	Water Environment Federation
WERF	Water Environment Research Foundation
WWTP	wastewater treatment plant